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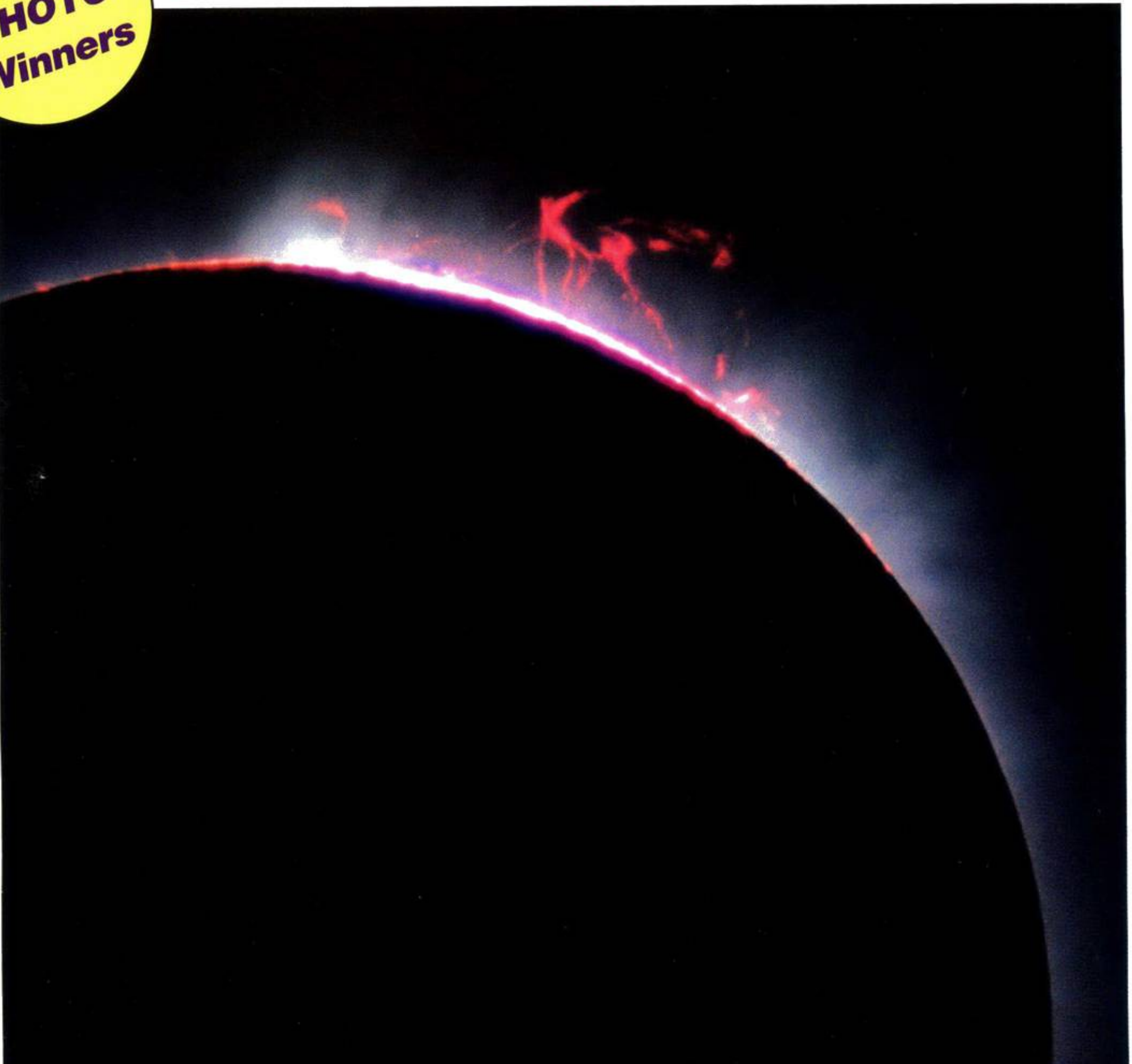

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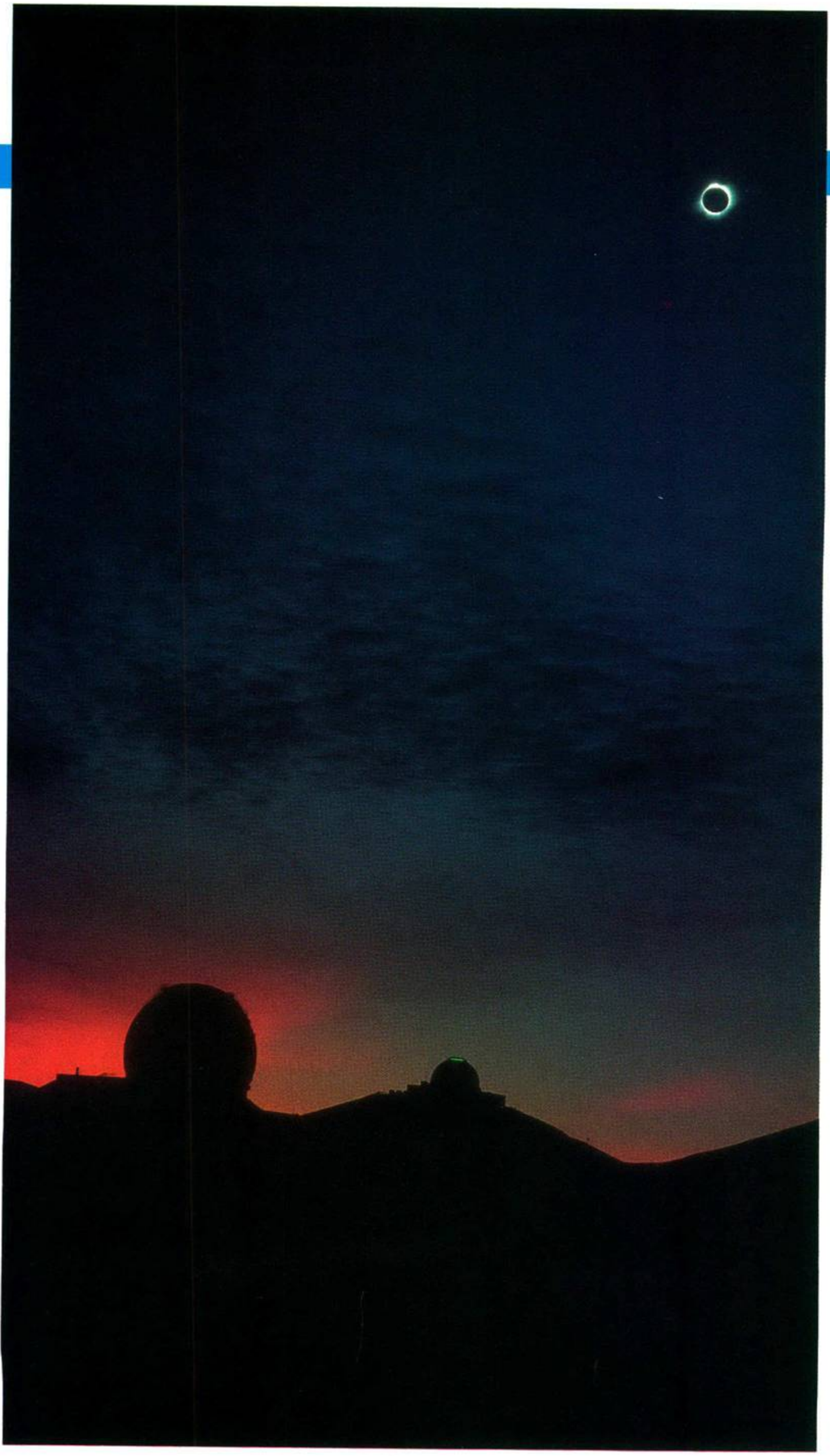
ON THE COVER: Fiery tongues of gas arching far above the solar surface burst into view when the Moon covered the Sun during the July 11 eclipse. For more of the best eclipse photos, see page 32. Photo by Rajiv Gupta.



A MOUNTAINTOP OBSERVATORY offered a unique vantage point for viewing July's solar eclipse. This double exposure (taken without moving the camera) shows the totally eclipsed Sun above the observatories on Mauna Kea on the same frame as sunrise light taken 30 minutes before totality. Photo by Oluf Nielsen and Barney Magrath.

ASTRONOMY®

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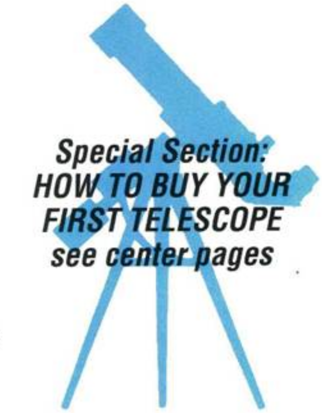

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Behind the Scenes

REMEMBERING THE GREAT ECLIPSE

For the past month, envelopes and packages full of eclipse pictures have flooded into our offices. As our eclipse story team of Rich Talcott and Dave Eicher opened the packages, we'd crowd around for a closer look at the latest goodies. As the selection process drew to a close, Rich and Dave presented a huge photo show to the staff and rated each picture on how many "ooohs' and ahhhs" it drew. Thanks to Dave and Rich for taking on this monumental task, and thanks especially to Rich for making the final cut and writing the story that begins on page 32.

I would like to express my personal thanks to Joe Chamberlain, Jim Sadler, and Ed Love. Together with the staff of the Adler Planetarium in Chicago and the staff of Love to Travel in Detroit, Joe and Ed put together an outstanding cruise, and meteorologist James Sadler directed our ship, the *Viking Serenade*, to a large patch of clear sky in the Sea of Cortez. I was aboard, as Adler Planetarium faculty, to teach safe eclipse viewing and eclipse photography and can attest to the smoothly run expedition, inspiring lecture program, and awesome view of the eclipsed Sun. Thanks again, Joe, Jim, and Ed.

Thanks are also due to Joel Harris and the staff of Twilight Tours. On this land-based expedition to Baja California were ASTRONOMY editors Alan Dyer, Dave Eicher, and Rich Talcott. Our coverage in the October issue spotlighted the Twilight Tours expedition and the unforgettable experience of viewing and photographing the eclipsed Sun despite clouds that formed during totality.

Finally, I want to thank the leaders of *all* the tours and groups that took ASTRONOMY's readers to see this glorious eclipse. You provide a valuable service to the community of amateur astronomers, and we appreciate it. That huge, spiky corona with its long streamers is a sight we'll never forget. The Great Eclipse of 1991 was a stunning success, and will, I am certain, be remembered for a long time by everyone who saw it.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

P.S. I want to highlight our new newsletter for astronomy clubs and societies. Called the *ASTRONOMY Network News*, it's intended to help club officers nationwide with an exchange of tips and ideas that can help make your astronomy club more fun. Whether you're a brand-new club with six members or a well-established society, you'll enjoy *ASTRONOMY Network News*. It's free; all you have to do is send a list of the names and addresses of your club's officers to Kalmbach Publishing Co., Attention Tammy Scherbarth, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187.

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Letters

In the Wrong Place, but at the Right Time

We were situated in the Waikoloa region, one of the driest and meteorologically most stable regions of the island of Hawaii. Yet the cloud cover was nothing short of spectacular.

In ancient Hawaiian lore, a total solar eclipse was explained as the Moon goddess Hina consorting with the Sun god Kane. However, it turns out that Hina is also the goddess of the clouds, and there is no doubt that she ruled the day. — *John F. Babson, Honolulu, Hawaii*

Okay, Okay! Instead of staying on the cruise ship *Jubilee*, we got off in Mazatlán to watch the eclipse. We got clouded out while the passengers on board the ship saw most of the eclipse through thin clouds. If any of the successful passengers would like to take pity on us and share photos or other information, we would appreciate it. Please send to: The Mazatlán Six, 800 W. Addition St. Apt. #2, Martinsburg, WV 25401. — *Betty Wasiluk*

Wanted: Best Eclipse Photo!

I am offering a prize of $1,000 for the best July 11, 1991 eclipse photograph showing the eclipsed Sun, the stars Castor and Pollux, and any planets. The photograph must have been taken between second and third contact, and the slide or negative must have had the time and/or date recorded on it by a camera databack.

My interest in this photograph is to disprove the astrological notion that the Sun was in Cancer on July 11 by showing that the Sun was really in the constellation Gemini. For additional information, please write to me at the address below and include a self-addressed, stamped envelope. Overseas correspondents should enclose international postage vouchers. — *Ben Mayer, Problicom Bulletin, 1940 Cotner Avenue, Los Angeles, CA 90025-5698*

An Unusual Eclipse Memory

Alan Dyer described multiple images of the partially eclipsed Sun formed by trees in his article "When Worlds Align" (July 1991 issue). I once saw this in a small town near Hannover, Germany, in July 1945. I was a doctor to a British Army unit at the time and assumed that the crescent images were caused by a partial solar eclipse. But more pressing concerns put it quickly out of my mind. — *Guy Richards, Vancouver, British Columbia, Canada*

Astronomers and the Media

I have been the PR director for the Boise Astronomical Society for many years. Since amateur astronomers are often locally the "official" source of information for astronomical events, I feel it is important to keep in close communication with the media. As a result of cultivating good relationships with our local media, the B.A.S. enjoys a great deal of attention for our events.

The local newspaper announces our annual star party for the public. We also get live, on-the-spot coverage from our local television stations. Weather people seem to be the ones to contact; I have yet to meet a weather person who isn't interested in astronomy. This coverage attracts over 2,000 people to our event in a single evening.

If a club wants the support of the community, they need to have someone in their organization who can reach out and cultivate the resources in the media. Become active in community events and share your hobby with others. Who knows, you could be the person who sparks a life-long interest of astronomy in a child. — *Arthur R. Martini, Boise, Idaho*

Apochromat Color

The June 1990 issue and the July 1991 issue reviewed apochromatic refractors. Both articles discussed the out-of-focus color as though it had some significance. Why? I have always been under the impression that the various wavelengths are brought together in sundry ways in an apochromat, so little about their optical quality can be discerned by viewing their out-of-focus color. I cannot see where this test would yield any useful information. — *Susan C. French, Scotia, New York*

— *You are correct in stating that apochromats bring different colors together in many different ways. But the out-of-focus test is still a valid method of testing how well the colors are brought together. Although individual colors may be different for different apochromats at the same out-of-focus position, the presence of color indicates how well the lens system has been corrected.*

A Greek Amateur's Attempts

It's fun to read ASTRONOMY magazine each month knowing that in another part of the world people also love looking at the night sky. Aside from reading about astronomy, I decided I needed a telescope too. A visit

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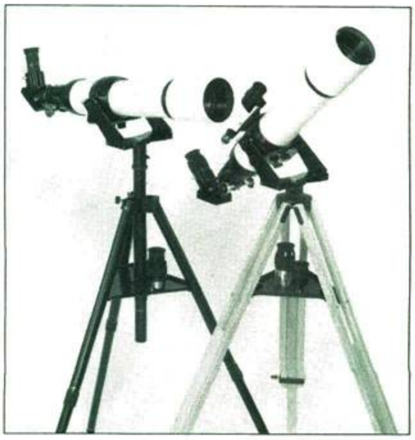

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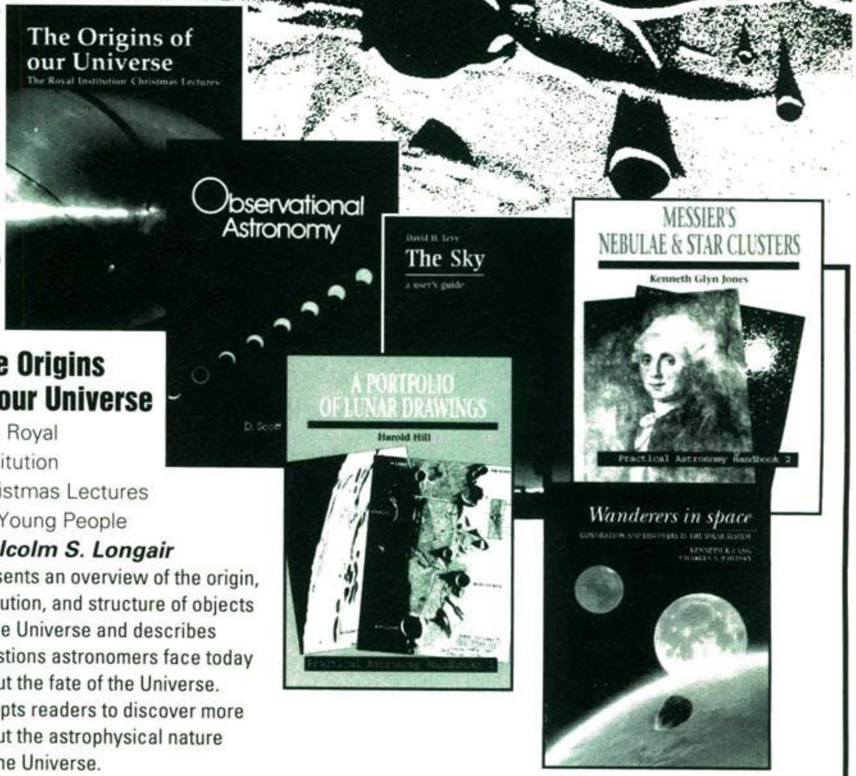
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It is difficult to be an amateur astronomer in Greece since there are few persons with whom to share this interest. Also, there is considerable light pollution in Athens which makes observing difficult. Still I am proud of the Greek contributions to astronomy, and I continue to enjoy my hobby despite the difficulties. — *Kostas Dardalis, Athens, Greece*

Comet Halley Outburst

The June 1991 AstroNews reports that a dramatic outburst has been observed from Comet Halley. Would not such an eruption alter the comet's path the way the orbital maneuvering engines change the space shuttle's orbit? — *Raymond Jack Guimond, Pine Falls, Manitoba, Canada*

— Continued expulsion of gas and dust from a comet does alter its orbit. The outgassing of Comet Halley during its last passage around the Sun caused it to arrive four days late at perihelion. However, a single outburst like the one in February is not sufficient to noticeably change the comet's orbit.

Intelligent Life?

Ken Croswell in his article "Does Alpha Centauri Have Intelligent Life?" (April 1991 issue) discusses the frequency of Earth-like planets and the conditions needed to create them. I suggest that life-bearing worlds may be rarer than implied in the article.

In addition to the effects of stellar type, planetary size and the distance between the planet and the star, one should consider what will happen to life once it evolves and the effect that life will have on its environment. The mere fact that conditions may permit life to develop does not mean that those conditions will continue to be favorable. — *Gerald Solof, San Diego, California*

Regal Rigel

Two small corrections to the interesting article about Rigel by Peter Jedicke and David H. Levy (February 1991 issue). Hydrogen burning is a more efficient energy source than helium burning, yielding more than three times the energy per reaction cycle. Also, recent calculations of the conditions inside stars indicate that helium burning starts later in massive stars than first thought. The major source of energy for Rigel is hydrogen burning in the thin shell around its helium core. — *Mirek Plavec, Department of Astronomy, University of California, Los Angeles, California*

Your Redshifts Have the Blues

The article "Is Cosmology a Sometime Thing" by Tony Rothman (July 1991 issue) is fascinating, but mixes up the redshifts one would see in a closed, collapsing universe. The most distant galaxies would continue to show redshifts since we are seeing far back into time, before the time of collapse. Nearby galaxies would show a blueshift owing to the collapse. Mr. Rothman is right, however, that the universe would show evidence for both the Big Bang and the Big Crunch. — *Devon Showley, Cypress, California*

Meteor Enthusiasts!

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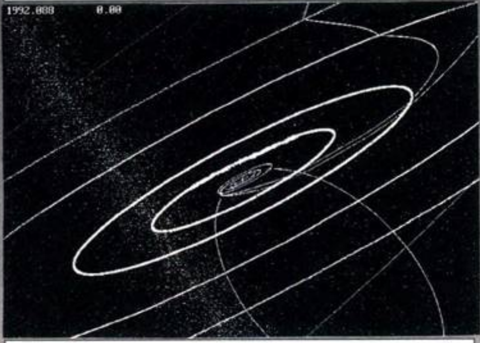
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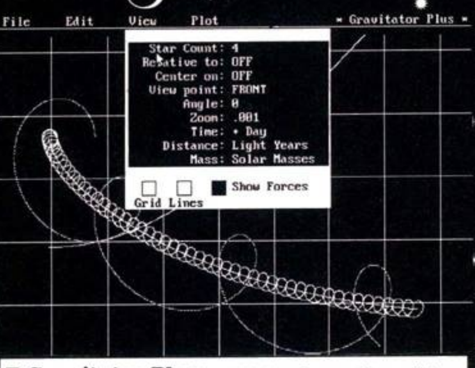

Star Count: 4
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Center on: OFF
View point: FRONT
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Time: • Day
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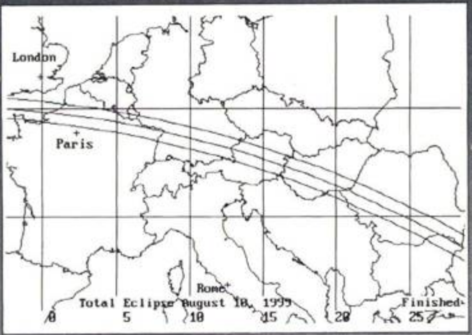

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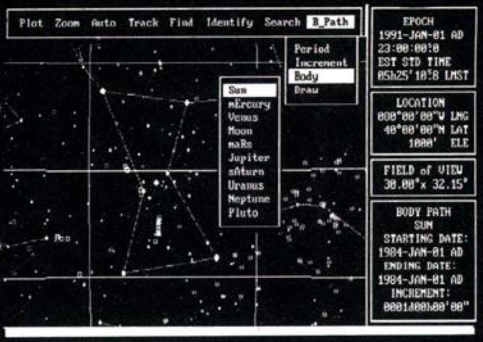

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40°00'00"N LAT
1000' ELE

FIELD of VIEW
30.00°x 32.15°

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1984-JAN-01 AD
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1984-JAN-01 AD
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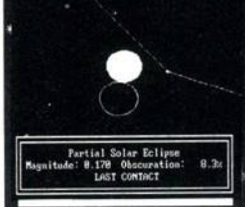
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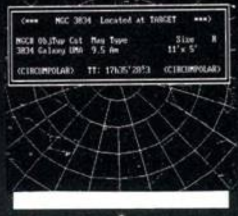
LAST CONTACT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THE MEXICAN SUN DANCE

by John & Stephanie Mood

South of the border, it was billed as *El Gran Eclipse de México.* As we sit in a cafe in Oaxaca, deep in the tropical highlands of southern Mexico, that boast doesn't seem so far-fetched. In spite of poor weather prospects and satellite photos showing cloud cover over the mainland, tens of millions of Mexicans did in fact witness the "Big One."

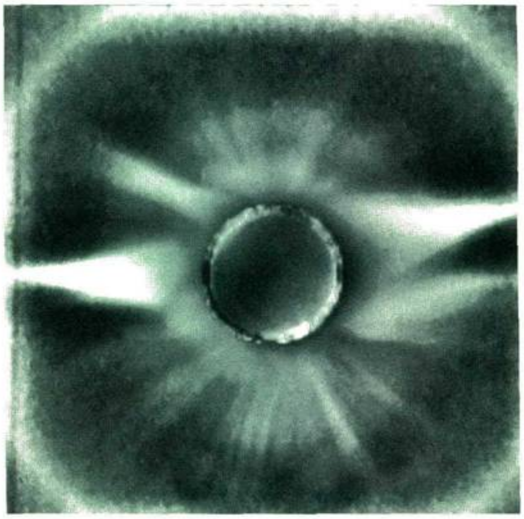
The Mexicans we talked to and observed with in San José del Cabo, Baja California, showed only delight in the eclipse. Indeed, it was a holiday. Shops and restaurants closed. At our hotel, a sign told us not to expect our rooms made up until after the eclipse. We saw all six minutes and 20 seconds of totality under pristine skies at a local golf course. As totality approached, five groundskeepers moved closer to us, running up for looks in our telescope when we beckoned. At second contact, their cheers echoed with ours and those of others who dotted the surrounding hills.

The contrast between the rumors we had been hearing in southern California during the months preceding the eclipse and what actually happened in Mexico was startling. The rumors painted a bleak picture: Only 25,000 tourists would be allowed into Baja California Sur during the week leading up to the eclipse. Camping permits would be issued for $60 a day per person, with a six-day minimum, for a total of $360! Little or no extra gas would be available. And hotel receipts, along with visas, would be needed to cross the border. Suzanne Gedance, a spokeswoman for the National Society to Prevent Blindness, declared, "It is not safe to look at an eclipse at all, even if it's absolutely total." All this appeared in the normally reputable *Los Angeles Times.* By contrast, a Mexican network newscast televised from Tijuana in May included an informative 15-minute segment complete with clever visuals and practical suggestions for viewing the eclipse.

The Mexican government was going to great lengths to make the eclipse a genuine, and safe, national fiesta. The Ministry of Health distributed millions of rectangular mylar viewing filters across the country. The Government Tourism Office prepared a gorgeous packet of nine fold-out cards with spectacular visuals and accurate timings, showing the eclipse path state by state across Mexico. Its distinctive logo and gilded printing bespoke months of careful planning. Even individual states and cities made separate plans for celebrations and programs on eclipse day. The high probability for *nublado* (cloudiness) notwithstanding, there was sufficient *despejado* (clarity) that most people on the mainland saw enough of totality to make it truly the *eclipse del siglo* (eclipse of the century) as advertised.

We learned about these extensive preparations only afterward, when we traveled to Mexico City and Oaxaca the week after the eclipse. We read papers, viewed telecasts, and talked with virtually everyone we came in contact with. "*¿Vio usted el eclipse?*" we would ask. "Did you see the eclipse?"

In Mexico City, a taxi driver told us he saw it all, *la corona* and *las rosadas protuberancias* (the red prominences), but he seemed only mildly interested, as if the scene had perhaps cost him a fare or two. In contrast, a young man in the tourist office at the international airport was enthralled. He had gone especially to a site near Puebla where the Great Pyramid of Cholula looms, the largest structure ever built by humans.



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This is considered one of the holiest places in Mexico because Quetzalcoatl, the legendary feathered serpent, lived there in exile in 900 A.D. "I was there," said the proud clerk. "I saw with my own eyes, no camera or TV, this great natural phenomenon."

Big celebrations were held outside Mexico City at Teotihuacán's Pyramid of the Sun, the third largest structure in the world, but unfortunately clouds obscured the eclipse. Mexico City itself was partly cloudy, and the 18 million people in its metropolitan area viewed the eclipse with enthusiasm — *estupendo, fantástico, muy bonito,* they said on TV. It was the largest group of people to view a total solar eclipse in history and they seemed to know it.

Oaxaca [pronounced wuh-HOCK-ah], a modest-sized city of a couple hundred thousand people, also had a large celebration. The local observatory featured speeches, dances, and *escenificaciones* (dramatizations) on eclipse day. A new mural with a two-headed snake in a figure-eight surrounded by the Sun, Moon, and planets commemorating the eclipse was unveiled nearby. There is also a long-running eclipse show at the planetarium.

Thousands went to the 15-square-mile Monte Albán outside Oaxaca, where the festivities centered around *Danzantes,* the Building of the Dances, which dates from 800 B.C. (almost half a millenium before the Parthenon). *El Imparcial,* one of Oaxaca's half-dozen daily newspapers, described the sheer silence of the crowd engaged in a "meditation based on prehispanic philosophy" (which that sacred site represents) and a fusing of the old and new cultures.

The streets of Oaxaca were empty as a result of this exodus, leaving the city semi-paralyzed. People who stayed in town took to the roofs to watch the event. Some, of course, feared eye damage. Three young women giggled as they told us their mothers would not let them view even partial phases of the eclipse through filters for more than four seconds at a time and *el anillo del diamante* (the diamond ring) at all. Still, they seemed to have caught the festive spirit.

We spent one morning at the Oaxaca library poring through Mexico City newspaper accounts of the eclipse. The sedate *Excelsior* put the eclipse in small print at the bottom of page one and reported it in stiflingly stuffy prose. *Novedades* gave it a full front-page headline treatment, with on-the-spot reporters in a half-dozen cities (including Cabo), swinging from "rah-rah" enthusiasm to scientific importance while also injecting a bit of skepticism, asking sarcastically, "*¿Eclipse del milenio?*" (millenium), knowing full well about the famous Mexico City total eclipse of August 23, 1691.

The tabloid-format *La Jornada* gave the eclipse the full pop treatment with lots of pictures. Its front page shouted, "The Shortest Night in 1,000 Years!" but included three excellent photos, one each from Mauna Kea, Baja, and Monte Albán. Several poems and a number of political cartoons capitalizing on the eclipse were scattered through its pages. "For Those Who Didn't See the Details," there was a blank square enclosing a large black circle. A photo of a bare foot silhouetted against a pyramid and the sky was captioned, "Foot Without Filter during Total Phase of the Eclipse at the Pyramid of the Sun."

As this eclipse traversed Hawaii, Mexico, and Central and South America, it brought viewers a mixture of reactions. But not in Mexico, a nation whose cultural history for millenia has revered the Sun. Here it was virtually a nation-wide solar eclipse fiesta. And we were there to share this electric experience. *¡Nos gustó mucho!* — We liked it very much! As much as the Mexicans themselves did.

THE VIEW FROM THE SUMMIT

by Barney Magrath

You couldn't ask for a better site for viewing a total solar eclipse than the summit of Mauna Kea. This dormant Hawaiian volcano, which rises 13,756 feet above sea level, is the best observing site on the planet. By a great coincidence, the path of totality of the July 11, 1991 solar eclipse passed right over Mauna Kea. I was one of the fortunate few to be on the summit during the eclipse, and it's an experience I won't soon forget.

My partner, Oluf Nielsen, and I spent the night before the eclipse camping on a knoll beneath the sacred summit of Pu'u Poliahu. This summit lies at an altitude of 13,631 feet directly west of the nine major observatories on Mauna Kea. Locals warn against camping on

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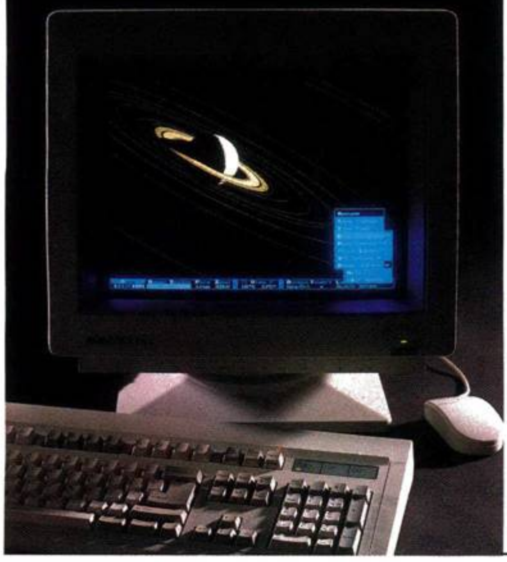

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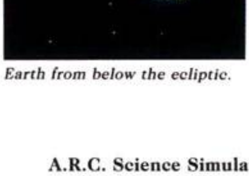
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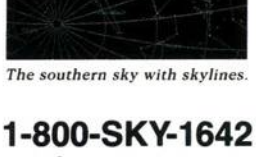
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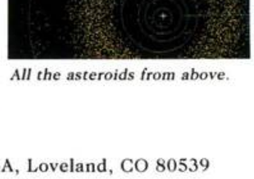
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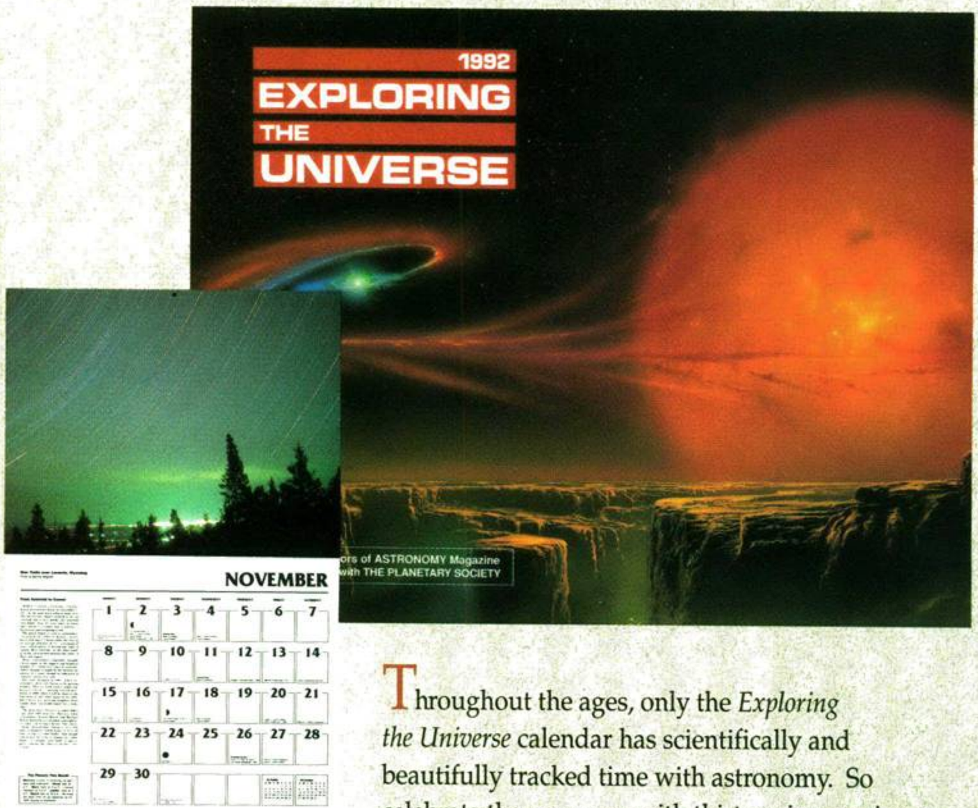

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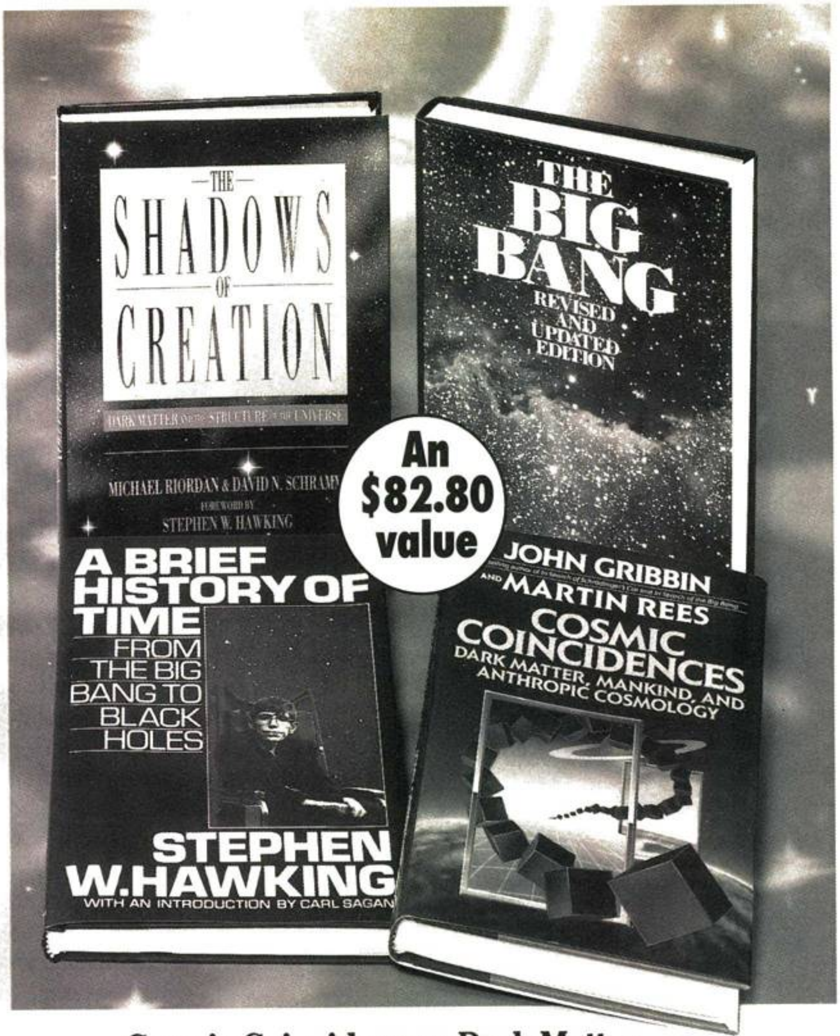
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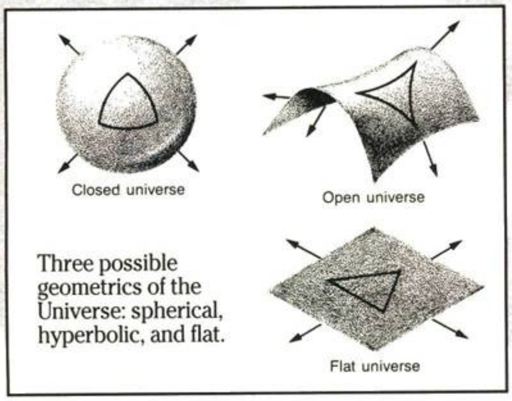

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Astronomy 11/91

Pu'u Poliahu, lest the inhuman Hawaiian nightwalkers discover and then slay you. Apparently they weren't very bloodthirsty that night, because we lived to tell this tale.

What *is* inhuman about camping on this rough heap of cold cinders is the high-altitude exposure. Mountaineers endearingly refer to this high altitude region as "the inhuman zone" because, until the body adjusts to the lack of oxygen, altitude sickness is a constant threat. Just to be safe, we took along some bottled oxygen and used it as we set up our photographic equipment late into the night. We didn't breathe the oxygen while we slept that night — we didn't sleep! We were too excited about the upcoming eclipse.

I spent a lot of time looking at the night sky and was quite surprised to see that it was not all that dark. The sky brightness had increased dramatically over the previous week, even at Mauna Kea, owing to high-altitude dust from the eruption of Mount Pinatubo in the Philippines. (During the day this volcanic dust looks like a halo of brown smog around the Sun.)

As eclipse day dawned, we noticed another source of obscuration — high, thin cirrus clouds. Once the partial phase began — about 40 minutes after sunrise — the obscurations seemed to lessen, though they did not disappear. The sky in the direction of the rising Sun appeared more white than blue. As the Moon's umbra drew closer we noticed a sharp drop in temperature. We quickly put our hats and gloves back on while the temperature dropped to 34° Fahrenheit. At least we were lucky that the wind was calm.

About three minutes before totality we heard a shout from across the mountain: "Look at the shadow!" I glanced in the shadow's direction but saw nothing unusual. I then removed my dark-adapting glasses and looked again. Sure enough, there it was. In the distance, the Moon's shadow had a bluish color similar to what you see underneath a thunderstorm, while its edges were soft and contained reddish, golden horizon colors. Although the shadow was racing toward us at 6,000 miles per hour, we did not perceive any motion in it.

As totality bore down on us, all we could do was gaze at the spectacle. It was as if someone grabbed our heads and forced us to look up. We first saw the corona a full 15 seconds before totality began. It looked like a sharply delineated collar of white fur encircling the Moon's dark disk. Totality blanketed the Mars-like landscape of Mauna Kea with a soft greenish-yellow glow. The corona then appeared pearly white and extended 1 to 2 solar radii.

As my mind and eye stored visual impressions, a tape recorder stored my excited verbal descriptions. (I had brought along two tape recorders — one for prompting myself with questions and the other to record my answers.) This is what I saw: During totality the corona shone with the cleanest, purest white light I have ever seen. Imagine transparent fiber optic hairs of all different lengths emanating from the Sun. Then fill that environment with the green light of searing hot iron vapor. It sounds weird, but that's the impression I got. I couldn't see any details in the outer corona because the background sky brightness was so high. In fact, I saw no stars at all. The astronomers later told me that the sky brightness was five times the normal value in the optical and 100 times normal in the infrared.

I also observed the color of my surroundings by looking at the white surface of the Keck telescope dome. During totality the dome appeared greenish yellow. Suddenly, about 30 seconds before the end of totality, the color of the ambient light turned a pale blue as a new layer of the Sun's atmosphere was exposed. Perhaps this was the "transition region" being uncovered. This is the region where the Sun's temperature rises from 4500 K in the chromosphere to 1,000,000 K in the corona. Astronomers don't know much about this region, which is why several observatories on Mauna Kea had designed experiments to look at this region.

Next, very dramatically, the diamond ring appeared and totality was over. But wait. Echoing what happened at totality's onset, we can still see the corona for 15 seconds!

As the Moon's shadow raced away, I looked down at the rest of the island and realized just how lucky we were. Half of the Big Island was completely overcast, and to make matters worse, the clouds were thickest in the very area the forecasters said would be clearest! As the sky grew brighter, the temperature quickly rebounded to a relatively toasty 45° F. With the rise in temperature came cumulus clouds, which soon completely obliterated the clear sky we had had. Two hours after totality ended, it was pouring rain at the summit. Luckily, for us, the rain came too late to dampen our spirits. ☐

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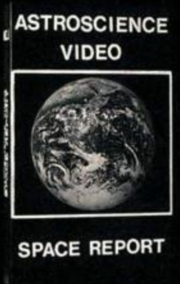

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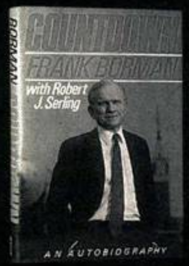

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LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices.

LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

Galaxies NGC 4631 (left) **and NGC 4656/7** (right) **in Canes Venatici.** 50 minute exposure by Martin Germano using 2415 hypered in a LUMICON Hyper-Kit and an 8" f/5 telescope with a LUMICON 2" Newtonian Easy-Guider. Much detail can be seen in 9th magnitude NGC 4631. Look for nearby 12th magnitude NGC 4627. NGC 4656/7 has an interesting hook; look for the hard-to-see faint extension doubling its length.

TELE VUE™ EYEPIECES USE THE BEST!!

ALL IN STOCK!

Item	Price
Oracle 3" f/7.4 Triplet Apochromat	$750
Genesis 4" f/5 4 element fluorite	$1560
Renaissance 4" f/5.5 refractor	$1560
Complete Equatorial Mount	$795
Motor Drive for above mount	$198
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	$89
1.8x or 2.5x Tele Vue Barlow Lens	$89
2" Giant Barlow	$219
32mm Plossl, widest true field in 1¼"	$109
55mm 2" Plossl, widest possible field	$219
15mm Wide-Field, 1¼" eyepiece, 65°	$135
19mm Wide-Field, 1¼" eyepiece, 65°	$145
24mm Wide-Field, "superb," 65°	$169
32mm Wide-Field, 2" eyepiece, 65°	$239
40mm Wide-Field, "awesome," 65°	$299
4.8mm Nagler, 82° field	$149
7mm Nagler, 1¼" eyepiece, 82° field	$189
9mm Nagler, 82° field, "the best"	$219
11mm Nagler, 82° field, 1¼" or 2"	$235
13mm Nagler, 82° field, 1¼" or 2"	$249
12mm Nagler, Type II, 82°, 1¼"/2"	$249
16mm Nagler, Type II, 82°, 1¼"/2"	$289
20mm Nagler, Type II, 82°, 2" only	$340
1¼" Paracorr Visual Coma Corrector	$179
2" Paracorr Visual Coma Corrector	$298

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount $59.50
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	H-Alpha	(MV)
46, 48, 49mm	$47.00	$39.00
52, 55, 58, 62mm	$59.00	$49.00
67, 72, 77mm	$69.00	$59.00
82mm	$79.00	N/A

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

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NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" **$29.95** 1.52" **$34.50** 1.83" **$39.50**
2.14" **$49.50** 2.60" **$65.00** 3.10" **$89.50**

ENHANCED ALUMINUM STAR DIAGONAL

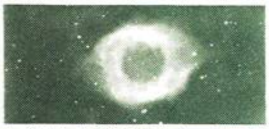
'90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

Item	Price
1¼" (1.32" mirror)	$99.50
2" (1.83" mirror)(see photo above)	$159.00

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

AMAZING OIII FILTER™



Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.

"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!
"Stunning is all I can say," says noted astrophotographer Jack Newton. *"Great for BOTH color and black and white photography."*

BEST WIDE-BAND FILTER!
*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complimentary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."*
Astronomy, Feb. 1991

Item	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	$79.50
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$119.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	$299.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$199.50
Set of both premium **DEEP-SKY** and **UHC Filters** (Save 11%) ... 1¼" **$159.50**; 48mm	**$279.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** **$99.50, 48mm**	$199.50
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines .... **1¼" $99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	$6.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	$20.00

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

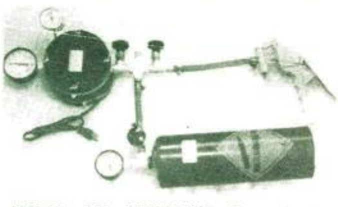
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**



MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller **$595**

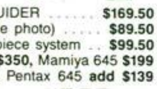
Temperature controller for any HYPER-KIT **$65**

Electric Vacuum Pump, Model R-10 **$295**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™



Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER **$169.50**
3X Relay Diagonal (see photo) **$89.50**
Illuminated reticle eyepiece system .. **$99.50**
Guider for Hasselblad **$350**, Mamiya 645 **$199**
Pentax 6X7 **add $119**; Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$198**, Mamiya 645 **$98**
Pentax 6X7 **add $119**; Pentax 645 **add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ..... **add $99.95**
Adapter for Hasselblad **$229**, Mamiya 645**$129**
Pentax 6X7 **add $129**; Pentax 645 **add $149**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector . $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) .. $99
NEW Deluxe Digital Qtz. Drive Correc. **$298**

NEW SR-G3200

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).***No C.O.D.s.***

Film Type, 35mm	Exposures	Price
2415, Ultra-fine B&W, red sens.	36	$10.95
SR-G3200, fastest of all, color neg	24	$13.95
Kodak Ektar 1000 fast, fine grain	24	$12.95
Fuji HG400 fine grain color neg.	12	$10.95
3M 1000, fastest slide film	12	$12.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

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NEW LOWER PRICES — NEW HIGHER PERFORMANCE — LUMICON® SKY VECTOR™

SKY VECTOR™ $399

LUMICON SKY VECTOR FEATURES:

- Digital right ascension readout to 1 minute of right ascension (RA)
- Digital decl. readout to 10 arc-min
- 4000 pulse (0.09° accuracy) high resolution encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, date, sidereal time, etc.
- 9V Battery lasts many nights.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision high resolution digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

LUMICON SKY VECTOR™ for Meade 2045B, 2080, 2120 *(Specify)*	**$399**
For Celestron C-8, C-11 *(Specify)*	**$399**
For Coulter Odyssey 8", 10", 13", 17½"	**$399**
For any alt-azimuth (Dobsonian) scope	**$399**
For Celestron C-14 (rewire dec. motor)	**$498**
SKY VECTOR KIT (for skilled ATM's)	**$369**

Reference catalogues (1000's of objects)

Burnham's *Celestial Handbook*, I, II, III	**$36.85**
Revised New General Catalogue (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II	**$29.95**

SKY VECTOR II™ $499

Only the LUMICON SKY VECTOR II has size, **true visual magnitude**, and complete **detailed visual description** for **all** 1500 objects in memory.

LUMICON SKY VECTOR II™ Computer with 1500 object memory, digital readout of coordinates, easy-to-use controls, object size, visual magnitude and detailed visual appearance descriptions.

Please specify telescope type:

LUMICON SKY VECTOR II™ for Meade 2045B, 2080, 2120 (*Please specify*)	**$499**
For Celestron C-8, C-11 *(Specify)*	**$499**
For Celestron C-14 (rewire dec. motor)	**$575**
For Coulter Odyssey 8",10",13"17½"	**$499**
For any alt-azimuth (Dobsonian) scope	**$499**
SKY VECTOR II (upgrade, computer only)	**$395**

The **LUMICON SKY VECTOR II™** has all the features of the regular SKY VECTOR, but has 1500 of the best deep-sky objects in memory, selected by noted observer Steve Gottlieb, along with their coordinates, size, true visual magnitude, and complete detailed visual descriptions. The sophisticated computer programming also will guide you to the object selected by displaying the real-time angular separation. Just move the telescope until the angles displayed become "0" using the "GUIDE" mode.

LUMICON SKY VECTOR II FEATURES:

- Includes **size, true visual magnitude & detailed visual appearance description** for all 1500 objects
- All 110 Messier objects
- Brightest 31 alignment stars
- User definable catalogue of 25 objects retained in memory
- 703 galaxies, groups & clusters
- 228 best open star clusters
- 170 best planetary nebulae
- 77 emission & reflection nebulae
- 10 best dark nebulae
- 107 best gobular star clusters
- 205 best colored & multiple stars
- Displays Uranometria 2000.0 chart no.
- ROM upgradable for planets, extended object lists, etc.
- TIMER function, elapsed time & stop watch
- 2 star alignment for alt-azimuth or equatorial telescope systems
- 1 star alignment if polar aligned
- Uses Epoch 2000.0 coordinates
- May align on any of the 1500 objects in memory

NGC SKY VECTOR™ $699

IMPROVED!

1528 Additions / Corrections

Improved NGC SKY VECTOR with over 8,000 object memory including complete and corrected RNGC catalogue, and IC and planetary catalogues.

LUMICON NGC SKY VECTOR FEATURES:

- All features of LUMICON SKY VECTOR II
- Complete *corrected* RNGC catalogue
- 574 nonexistent NGC objects identified
- 343 corrections to RNGC catalogue
- 203 best colored & multiple stars
- 140 "Best IC Objects" catalogue
- 306 best planetary nebulae selected by Jack Marling in separate catalogue listing
- 268 best "Non NGC/IC" objects catalogued
- "IDENTIFY" program helps you identify an unknown object seen in eyepiece
- "GUIDE" program leads you to object
- Detailed visual or photographic descriptions
- RS-232 port for computer access
- Includes planets ephemeris in computer

LUMICON NGC SKY VECTOR for Meade 2045, 2080 or 2120 *(Specify)*	**$699**
For Celestron C-8, C-11 *(Specify)*	**$699**
For Celestron C-14 (rewire dec. motor)	**$775**
For Coulter Odyssey 8",10",13",17½"	**$699**
For any alt-azimuth telescope	**$699**
NGC SKY VECTOR (upgrade, computer only)	**$550**

MEADE® TELESCOPES

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LUMICON ACCESSORIES

NEW PREMIER SERIES TELESCOPES

All Meade Premier Series telescopes **include Smart Drive (SD) permanent periodic error correction**, multi-coated enhanced optics (MCOG), Electronic Command Center (ECC), and **include** advanced LX6 all-electronic drive system. Select f/10 or f/6 optics, and select only the optional features you **need.** The 8" has a 6X30 finderscope and the 10" has an 8X50 finderscope. SD = Smart Drive.

2080 Model 40SD, 8" f/10	**$1650**
2080 Model 46SD, 8" f/6	**$1799**
2080 Model 50SD, 8" f/10	**$1950**
2120 Model 40SD, 10" f/10	**$2150**
2120 Model 46SD, 10" f/6	**$2298**
2120 Model 50SD, 10" f/10	**$2450**
Model 2600 16" f/10	**$10,950**

Options Enhance Performance

Super Wedge for 10"	**Add $299**
#39 Declination motor	**Add $109**
Digital setting circle	**Add $399**
2" Star diagonal	**Add $179**
LUMICON Cassegrain Easy-Guider *(Please specify camera)*	**Add $225**
LUMICON Giant Easy-Guider (for #40) *(Specify camera)*	**Add $395**
LUMICON Giant Easy-Guider (for #46) *(Specify camera)*	**Add $295**

PREMIER 2080 Model 50SD $1950

Meade Premier 2080 Model 50SD

COMA CORRECTOR

Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces. Clear aperture = 1.8".

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

2" DELUXE BARLOW

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x Multiplier Lens	**$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $59.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$59.50**
LUMICON 2" Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$37**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher, C-6, Meade 312, 321 refractor	**$30.00**
2" LUMICON EASY-GUIDER (state camera)	**$169.50**

SEEING THE HEAT OF THE NIGHT

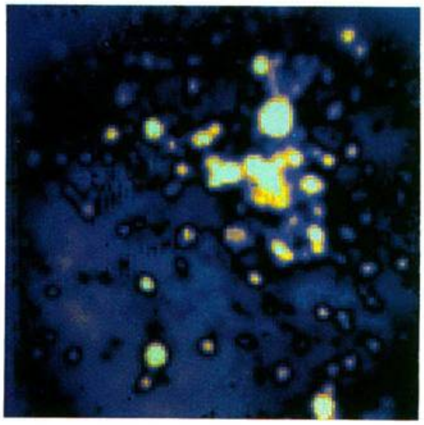
A camera created for the 120-inch Shane Telescope at Lick Observatory is providing new views of the planets, the center of the Galaxy, and other heat-emitting objects in deep space. The camera uses an electronic detector capable of "seeing" infrared heat energy and creating images much as a normal visible light camera does. The infrared-sensitive chip is structured like one of the charge-coupled-device chips found in home video and scientific cameras, with thousands of tiny pixels arrayed in a grid less than 1 centimeter square. The camera was developed by Kirk Gilmore, David Koo, and David Rank of the University of California at Santa Cruz using a detector made from a mercury-cadmium-telluride semi-conductor.

One image taken with the infrared camera shows stars and other objects as yet unknown at the center of the Milky Way. By comparing this image to ones taken over the next few years, astronomers hope to see changes in brightness in some of the individual objects. This in turn could provide clues to the identity of the energetic mystery objects at the center of our Galaxy.

The infrared images of Mars that Gilmore, Koo, and Rank obtained in 1990 will help astronomers track dust storms and find signs of gypsum, carbonates, and other compounds on the Martian surface that could be remnants of ancient ocean beds. On Jupiter, the hottest and brightest features are deep cloud decks. Infrared images of these clouds will help scientists track the weather patterns in the Jovian atmosphere. In the image of Saturn, the rings appear bright because of scattered light from the many icy particles that make up the rings. Astronomers may be able to analyze the image data to refine the estimates of the particles' sizes.

In the future, the camera team hopes to capture images of infrared sources first detected by the orbiting Infrared Astronomy Satellite (IRAS) in 1983. These warm spots in the sky, which are invisible in normal light, may represent new types of objects.

SEEING THE INFRARED UNIVERSE is now possible with electronic cameras equipped with a new generation of infrared-sensitive semiconductor chips. All these images were taken through the 120-inch Shane Telescope at Lick Observatory. Photos courtesy the University of California at Santa Cruz.



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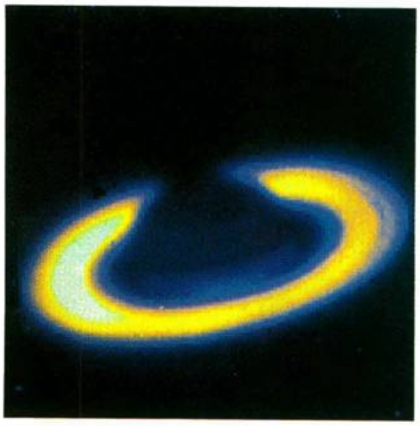

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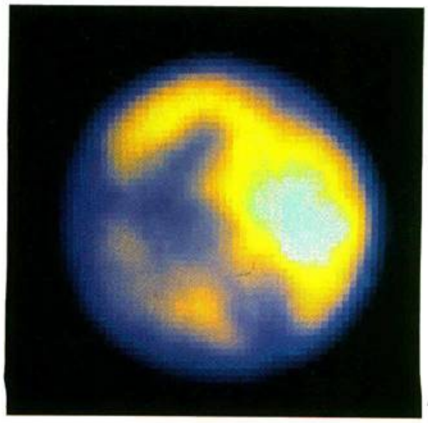

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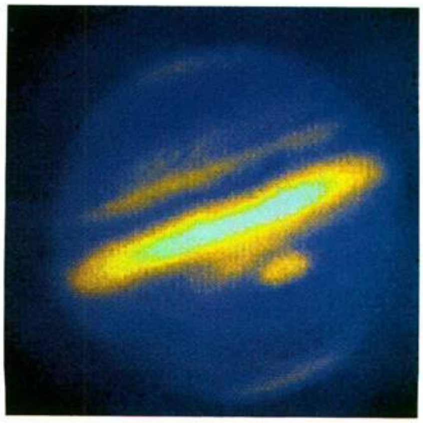

JUPITER

NEW VALUE FOR HUBBLE CONSTANT FROM DOUBLE QUASAR?

The value of the Hubble constant, a number that expresses the rate of expansion of the universe and thereby its age, has been redetermined based on measurements of a gravity-lensed double quasar.

The value of the constant is one of the most contested numbers in all of astrophysics. Two values, 50 and 100 kilometers per second per megaparsec, are the most often championed, with the lower value implying a 20-billion-year-old universe and the higher one a 10-billion-year age.

To determine the value afresh, a team of astronomers led by David Roberts of Brandeis University used the Very Large Array radio telescope to observe a quasar in Ursa Major that appears doubled. The quasar (0957+561) is actually a single object, but a galaxy lying between Earth and the quasar functions as a gravity lens to create a double image of the quasar.

Using many radio "snapshots" and a sophisticated data reduction technique, the team nailed down the time delay (1.40 years) between when a brightness change in one of the quasar images appeared in the other. This measurement coupled with the angular distance between the two images yielded a new measure of the Hubble constant.

The researchers' value falls between 46 and 69 kilometers per second per megaparsec. The astronomers note that

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the lower value assumes the lensing galaxy has no dark material associated with it, while the higher value would be the result if the intervening galaxy did contain dark matter. They state that the value of 69 is likely to be closer to the truth because, as many astronomers now believe, most galaxies probably do contain large quantities of dark matter.

While the scientists note that the new finding is unlikely to be the final word on the Hubble constant debate, they point out that the method they used avoids all the uncertainties found in conventional methods. (These necessarily make assumptions about how intrinsically bright objects are.) But because their value falls between the two extremes currently in vogue, they conclude, perhaps puckishly, that the scale and age of the universe is indeed known to about a factor of two.

CLOUDS FEED CENTER OF OUR GALAXY

A complex of strong radio sources called Sagittarius A is located near the center of the Milky Way Galaxy. Until recently, astronomers were uncertain about the relationship between molecular gas clouds and the compact radio source at the center, and about what fuels this powerful source. New observations suggest there is a physical connection between the gas clouds and the galactic center, and that the gas clouds are possibly feeding material into the center.

The molecular gas clouds surrounding the very center of the Milky Way Galaxy were recently surveyed by Albrecht Poglitsch of the Max Planck Institute and his colleagues using NASA's Kuiper Airborne Observatory. As reported in *Astrophysical Journal Letters* for June 20, 1991, the survey was performed in the far infrared at a wavelength of 158 microns. The central 160 light-years of the Galaxy were examined with a resolution of one arcminute, or $7\frac{1}{2}$ light years at the assumed distance to the center of 26,000 light years.

The astronomers found that the strongest far infrared emission came from the ring or disk surrounding the Sgr A West radio source (the "mini-spiral"). They also determined that the gas clouds are not simply rotating about the galactic center but are slowly spiraling in towards the center, establishing a physical connection between the gas clouds and Sgr A*, the compact radio source located within Sgr A West and believed to be at the center of the Galaxy.

From the masses and orbits of the gas clouds, Poglitsch and his colleagues conclude that a few tenths of a solar mass are added each year to the disk surrounding Sgr A West. Considering that a single cloud has a mass in excess of 100,000 solar masses, the gas clouds could feed material into the disk for well over 1 million years. This mass accretion may help to explain the powerful nature of the Sgr A radio sources.

CLOUDY STAR BIRTH IN ORION

The Orion Nebula is one of the most intriguing places in the Galaxy, an interstellar delivery room where new stars are continually being born. Now three Arizona astronomers have made radio observations that may have cracked its most guarded secret, what triggers that ongoing act of stellar procreation. They found possible evidence that the Orion Nebula's star-forming cradle lies in the collision zone between two vast clouds of interstellar gas and dust.

"We're not sure yet, but it's possible that such collisions trigger the formation of stars," says Arizona State University astronomer Susan Wyckoff. Along with graduate student Maria Womack and

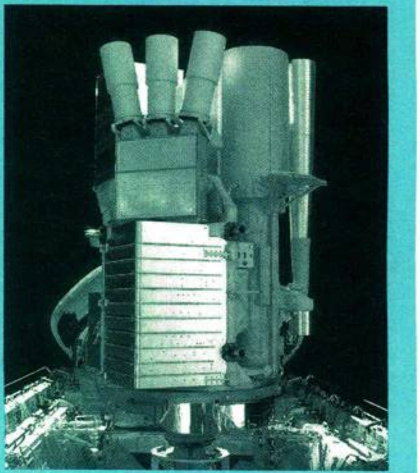
Space News

ASTRO TO FLY AGAIN

One of the most successful space science missions of the last few years won't be a one-flight affair. That was the good news for astronomers earlier this year when NASA announced that ASTRO will fly again. ASTRO is a pallet of three ultraviolet telescopes that fits into a shuttle cargo bay. Its first flight was in December 1990 when it flew for nine days aboard the shuttle Columbia. (See "ASTRO's Violet Universe" in the May 1991 ASTRONOMY.) It peered at targets both near and far that emit ultraviolet light, radiation characteristic of very hot objects and which can only be observed from above Earth's atmosphere.

At the time it appeared that ASTRO's first flight might also be its last. But the success of the first mission convinced NASA administrators to carve a place in the budget for a reflight on a future space shuttle mission. Said Lennard A. Fisk, Associate Administrator for Space Science and Applications, "We are delighted to be able to refly this proven scientific performer." David Huenemoerder, Program Scientist on ASTRO-1 added, "The ASTRO Principal Investigators and their teams will be very pleased. That first flight was just a taste of the scientific insights they expect to emerge from ASTRO-2."

The flight of ASTRO-2 will occur sometime after 1993. All three ultraviolet telescopes will be on board. Missing will be the Broad Band X-Ray Telescope (BBXRT) which accompanied the ASTRO-1 pallet in December. Since the upcoming Japanese/U.S. Astro-D satellite (no relation to ASTRO, the shuttle package) is expected to make observations in the x-ray spectrum similar to those that BBXRT could acquire, NASA decided to forgo the expense of reflying ASTRO's X-Ray Telescope.



THE ULTRAVIOLET EYES OF ASTRO *will have at least one more opportunity on a future shuttle flight to peer into the hot realm of the universe. NASA photo.*

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astrochemist Lucy Ziurys, she published the observations in the April 1, 1991 issue of the *Astrophysical Journal*.

The discovery of the multiple, possibly colliding clouds came as a surprise. "I didn't believe it at first," Ziurys says. "People had been studying this region for years without such a finding." At a relatively nearby distance of 1,600 light-years, the Orion Nebula is the closest star-forming region to Earth and a popular target for astronomers' telescopes, amateur and professional.

The discovery came as Womack was surveying 17 star-forming regions last April and May. Wyckoff explains, "She was looking for N_2H^+, a molecular ion that is different from the ones usually looked for. She was using the powerful new detectors of the National Radio Astronomy Observatory's 12-meter radio telescope at Kitt Peak.

"But instead of seeing just a single spectral line for that molecule, she observed two. That indicated a velocity difference between two clouds, which said they were moving relative to each other. On checking, Womack found that Orion's star-forming region lies right at the interface of these clouds," Wyckoff says.

Each of the clouds stretches for 50 light-years to either side of the star-forming region. Between them lie possibly 100 new stars, in an interstellar storm front a light-year wide and roughly 500 astronomical units long. The stars are "hot blues" that range in size from 100 times that of the Sun to a tenth its size. They are about a million years old — extraordinarily young compared to our 4.5-billion-year-old Sun.

Wyckoff doesn't rule out, however, that the clouds may not be colliding or causing stars to form — or even that the stars may have been triggered by some other process. The Arizona astronomers are making more observations of the region, and Womack is also looking at other star-forming regions to see if they too have multiple clouds. — *Steve Davis*

OLDEST STARS IN THE GALAXY

The oldest star known in the Milky Way Galaxy has been found by Timothy Beers (Michigan State University) and his colleagues. Believed to be 15 to 20 billion years old, the star has been labelled CS 22876-32 (CS for Curtis Schmidt, the telescope with which it was discovered).

The star was found as part of a survey of the metal content of stars in the outer region, or halo, of the Milky Way Galaxy. This survey is being conducted with telescopes at Kitt Peak National Observatory in Arizona and Cerro Tololo Inter-American Observatory in Chile. Beers and his colleagues gave a progress report of their work at the January meeting of the American Astronomical Society.

The standard model of the Big Bang predicts that the early universe consisted of primarily hydrogen and helium, with only a very tiny amount of light elements such as boron and beryllium. As the earliest stars burned hydrogen and helium at their centers in order to generate the energy needed to support the outer layers against the inward pull of gravity, the lighter elements were transformed into heavier elements, often called metals by astronomers. Elements like iron and nickel were produced by supernova explosions as the final nuclear reactions in the cores of massive stars became unstable. The relatively large metal content of the Sun is a result of many previous generations of stars slowly transforming light elements into successively heavier elements.

Very old stars should still contain only a small amount of metals since the stars formed from the metal-poor material of the early Galaxy and their nuclear reactions are insufficient to directly produce the heaviest metals. The metal content of CS 22876-32 was observed to be 30,000 times less than that of the Sun, which led the astronomers to conclude that this star must have been amongst the first to be formed in our Galaxy.

Beers and his colleagues believe that this is just the first of these very low metal content, or metal-poor, stars to be observed. As they continue their survey, they expect to find several stars with an even lower heavy metal content than CS 22876-32. There is a 50 percent chance that a star with 1,000,000 times less heavy metal content than the Sun may be detected.

This research has implications for our understanding of the number of supernovae which occurred early in the history of our Galaxy, and the distribution of their masses. The uniformity of the gas out of which our Galaxy formed may also be determined. Furthermore, as Beers and his colleagues detect heavy-metal-poor stars during their survey, they plan to reobserve these stars to determine the amount of light metals present. The amount of boron and beryllium found in these ancient stars will help astronomers to choose between cosmological models since non-standard big bang models predict that the early universe will produce 10 to 1,000 times more boron and beryllium than the standard model.

Amateur News

MASON-DIXON STAR PARTY A HIT

The wait was agonizing.

I watched nervously as one of the most knowledgeable and respected members of our astronomical society ascended the ladder alongside our recently completed, hand-built, 18-inch f/4.5 Dobsonian telescope.

His task was to point the telescope at the great globular cluster M13 in Hercules. He knew that M13 would be an excellent test for determining whether all the time and hard work we spent building this telescope had paid off. Other society members stood nearby, quietly confiding their expectations to each other, but I couldn't quite make out their conversations.

My thoughts were focused on seeing this celestial wonder as never before and on the added benefits this telescope would give us in promoting amateur astronomy. It was not the most grandiose telescope of the hundred or so present at the star party, but it was ours and we were proud of it.

Repositioning himself to peer through the eyepiece, he fine-tuned the pointing of the telescope and focused the 9mm Plössl. He then stood motionless. If we had done our homework correctly, and assembled and lined up all the optical parts precisely, he should be seeing the resplendent, crystal clear image of a million blazing stars. Everyone grew quiet, anxiously awaiting his composed, professional opinion. What we saw instead was a huge grin spread across his face as he proclaimed an un-

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pretentious yet commanding — "WOW!" A cheer went up from those of us who had helped build the telescope, and soon a line of eager observers stretched out into the night.

For me, this is what the 1991 Mason-Dixon Star Party was all about — the anticipation and excitement of seeing the wonders of the night sky and the satisfaction in watching the faces of the curious as they too viewed the universe firsthand. Only in its second year, this star party is already gaining public recognition for its excellent promotion of amateur astronomy.

Named for the famous Mason-Dixon line that forms the boundary between Pennsylvania and Maryland, this annual event is sponsored by the York County Parks Astronomical Society. The 1991 star party was held on June 14-16 in Spring Valley Park, York County, Pennsylvania. The park's secluded location offers great observing, yet it is conveniently close to major highways, restaurants, and lodging. Despite the proximity of these amenities, most of the 205 visitors chose to camp out under the park's beautiful clear sky amidst the rolling hills and serene countryside.

Not all of the star party's activities occurred under the stars, however. Every guest had the opportunity to lecture on any astronomical topic of their choosing, as long as it was preapproved by the society. This year's presentations included an exhibition of sketches and paintings by the 19th-century astronomical artist Leopold Trouvelot, a talk on the trials and tribulations of photographing the 1979 total solar eclipse from the inhospitably cold north, and a discussion on how to make a good reflecting telescope even better.

Two professional astronomers honored the star party with lectures on the latest in Earth-orbiting telescopic observations. Christopher Blades of the Space Telescope Science Institute showed some of the outstanding images returned by the Hubble Space Telescope and described what it was we were seeing. Gerard Kriss, the assistant project scientist for the Hopkins Ultraviolet Telescope, delivered the keynote address titled "ASTRO-1: A Space Odyssey."

Those taking a break from the daytime indoor activities witnessed a beautiful and awesome display of solar activity courtesy of a hydrogen-alpha filter attached to an 8-inch Schmidt-Cassegrain telescope. One sizable loop prominence riveted the observers to the eyepiece. Thanks to the wonder of videotape, those who missed the event in real time were able to see it later.

There were also plenty of things to keep the children entertained. After watching an introductory astronomy talk and video, the kids played "Invent An Alien." This game had the children draw their own version of what an alien creature on another planet would look like based on that world's particulars. Even H. G. Wells would have been impressed by some of their creations.

Of course, what's a star party without stars? Once the formal entertainment concluded each evening, the telescopes came out. Soon calls of "Here's a pretty view of M51" and "Take a look at Pluto" rang throughout the camping area. People even caught a glimpse of the Hubble Space Telescope soaring low over the southern horizon. But the most talked about celestial event of the entire weekend was the beautiful and rare gathering of Jupiter, Mars, Venus, and the crescent Moon.

Saturday morning saw a swap-and-sell flea market where participating vendors and guests happily exchanged their wares. A wide assortment of astronomical goodies were available, from comical T-shirts to miniature telescopes and astronomical paintings to Moon clocks.

Numerous astronomy-related door prizes helped to make the weekend all the more memorable for the lucky winners. One small boy won a Lumicon deep-sky filter but did not own a telescope to use it with. By the end of the weekend he had traded it for a good quality beginner's refractor owned by a sympathetic bystander. It would be difficult to argue who got the better deal.

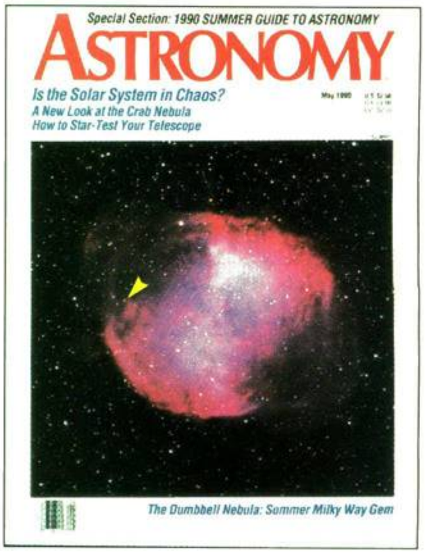
Such displays of friendship and congeniality among strangers help make the Mason-Dixon Star Party what it is. I hope all of you in the York County area of Pennsylvania will have the chance to join us next year. — *Gregory Markowski.*

CZECH AMATEUR DISCOVERS VARIABLE

A possible long-term, irregular Mira-type variable has been discovered in the Dumbbell Nebula (M27) by Leos Ondra, an amateur astronomer in Czechoslovakia. Ondra had been preparing a chart of the nebula and the foreground stars. He discovered the variable when he compared the cover photographs from the May 1990 ASTRONOMY and the Autumn 1990 DEEP SKY to his chart of the region.

As reported in the IAU Information Bulletin on Variable Stars (Number 3604), this star does not appear on about forty percent of the photographs of the Dumbbell Nebula taken in the last few decades, suggesting that the star is a long-term variable. Brightness estimates place maximum light at 15th magnitude. Estimates of other stars visible on these photographs indicate that the variable changes brightness over a large range. The variable's amplitude coupled with the apparent orangish color of the star at maximum light is evidence that this is most likely a Mira-type variable.

The estimated position of the variable is right ascension 19h 57m 01s, declination +22°37.2' (epoch 1950.0). □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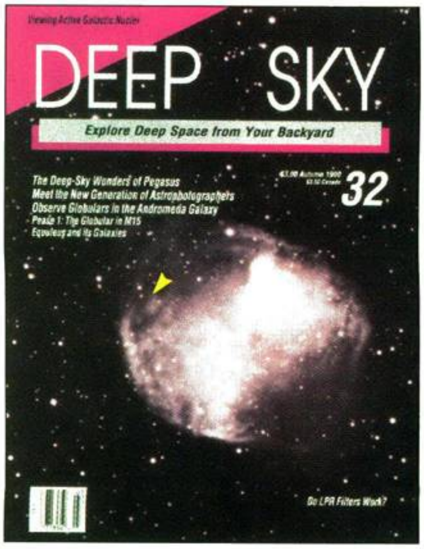
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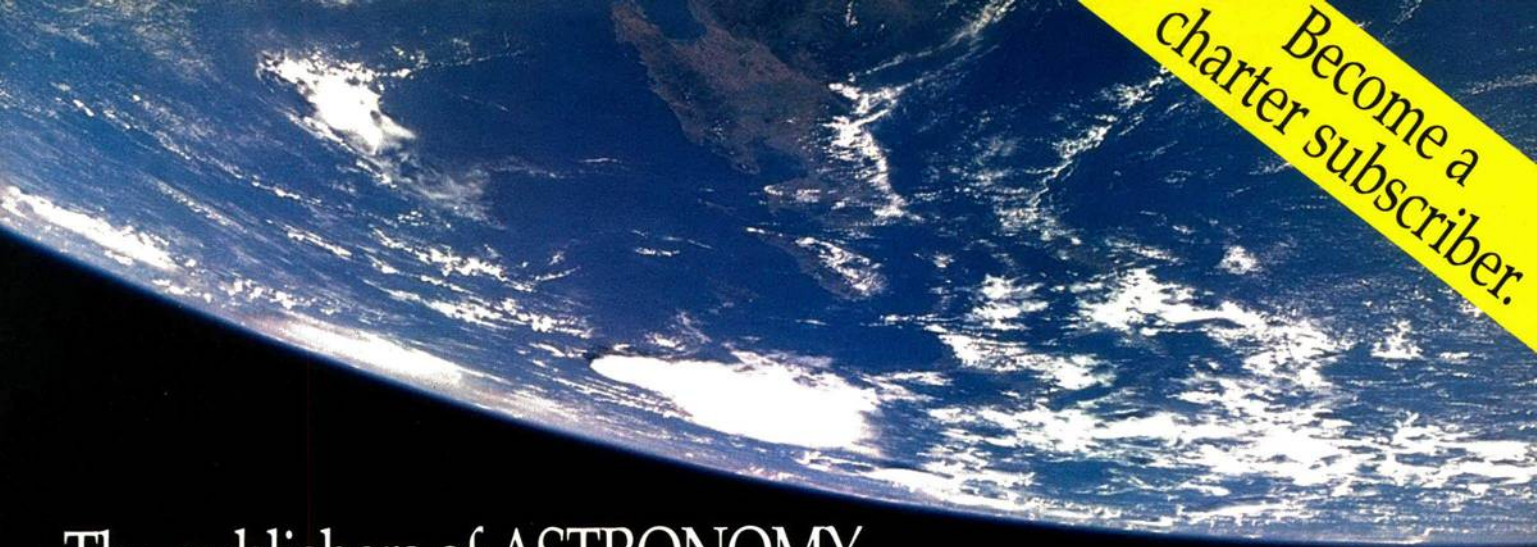

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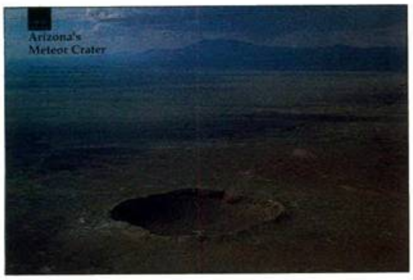

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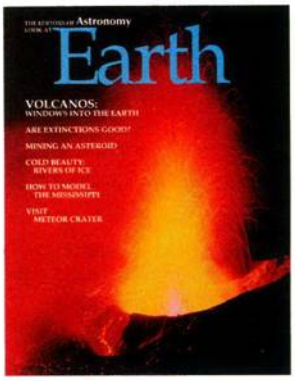
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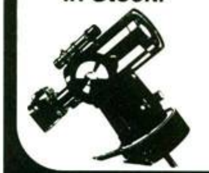

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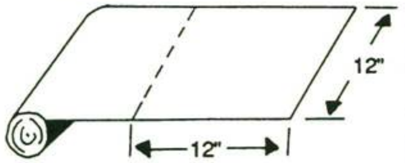

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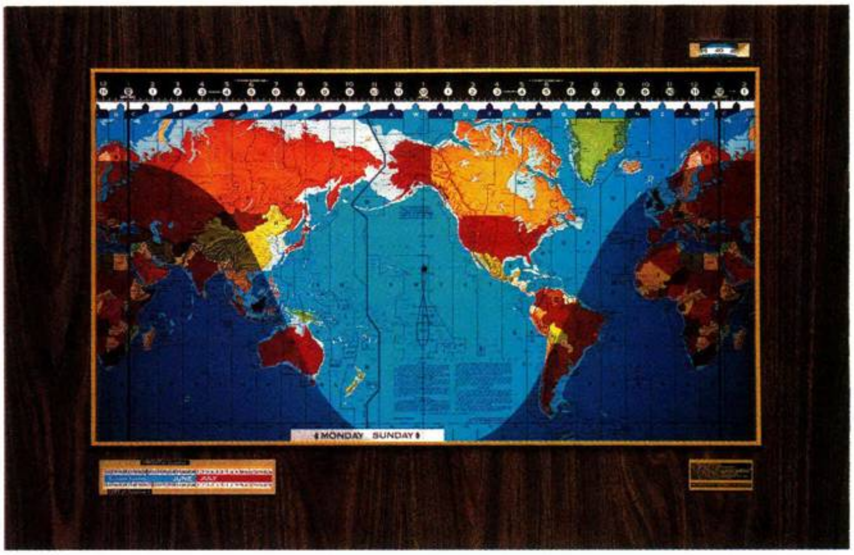

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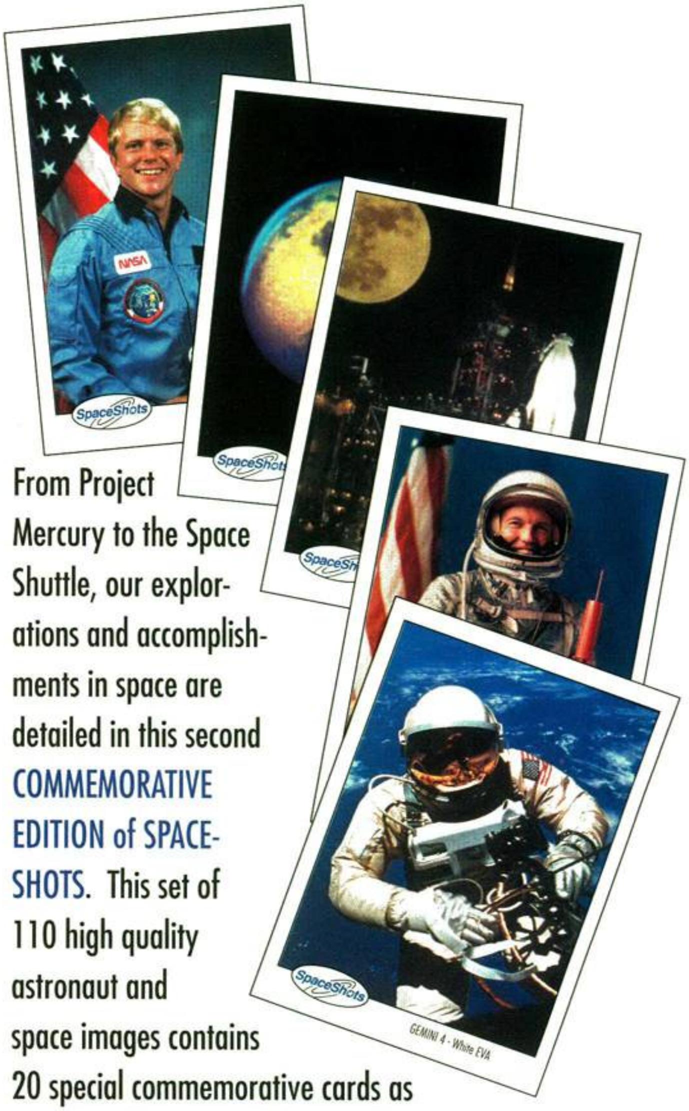

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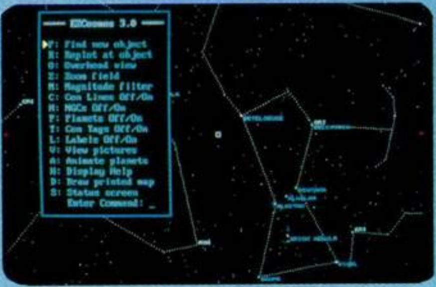

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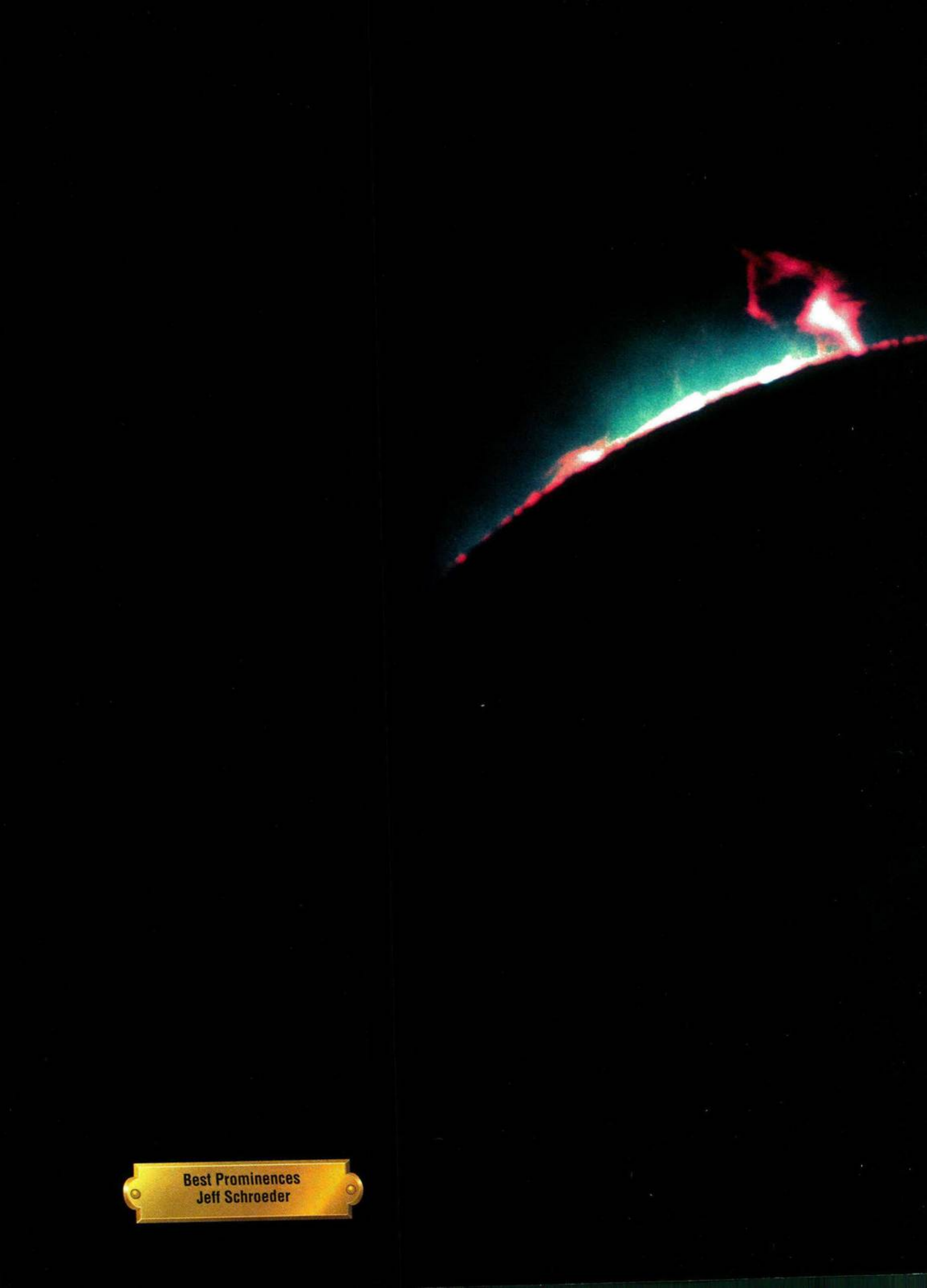
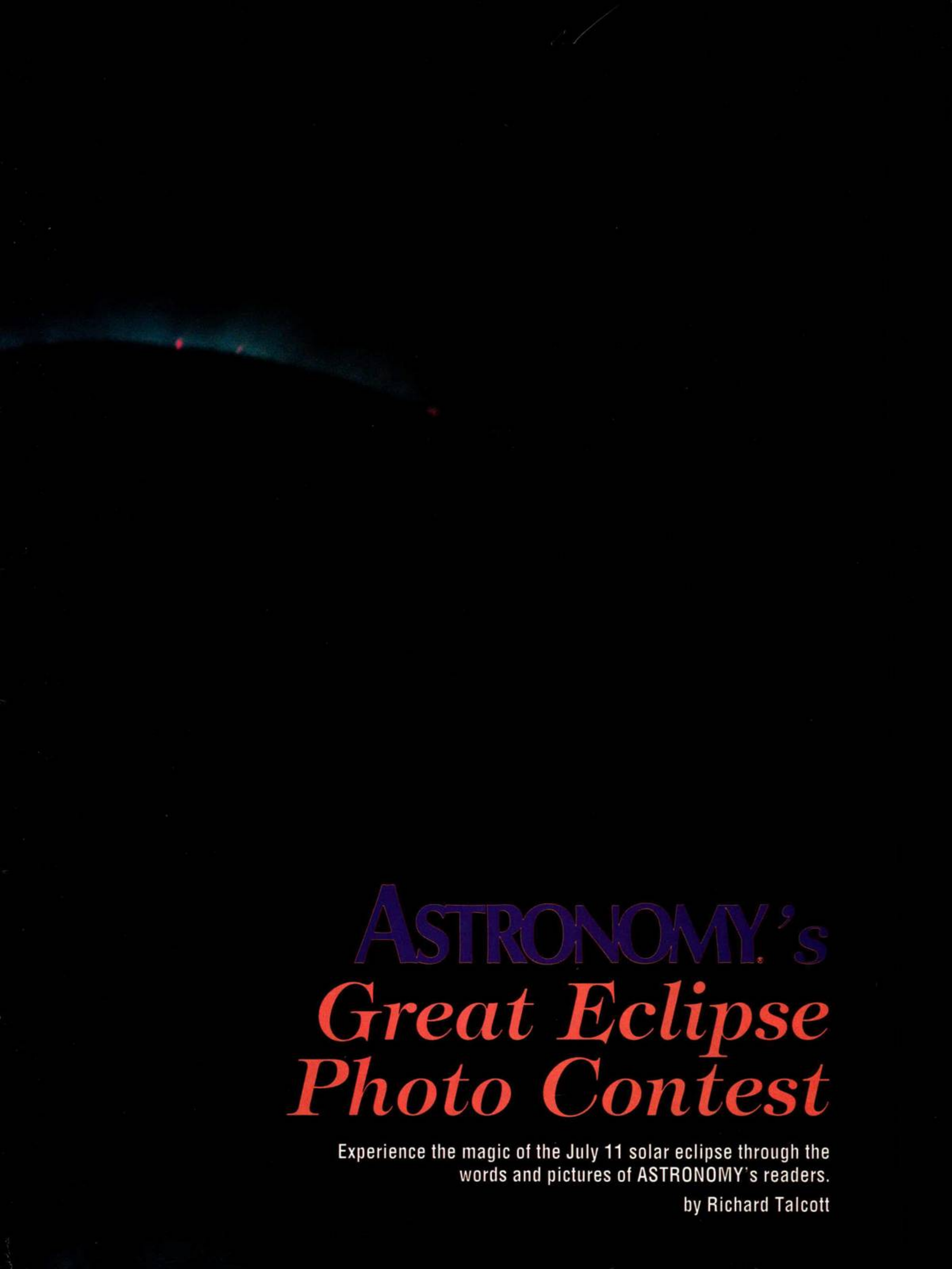


Best Prominences
Jeff Schroeder



ASTRONOMY's Great Eclipse Photo Contest

Experience the magic of the July 11 solar eclipse through the words and pictures of ASTRONOMY's readers.

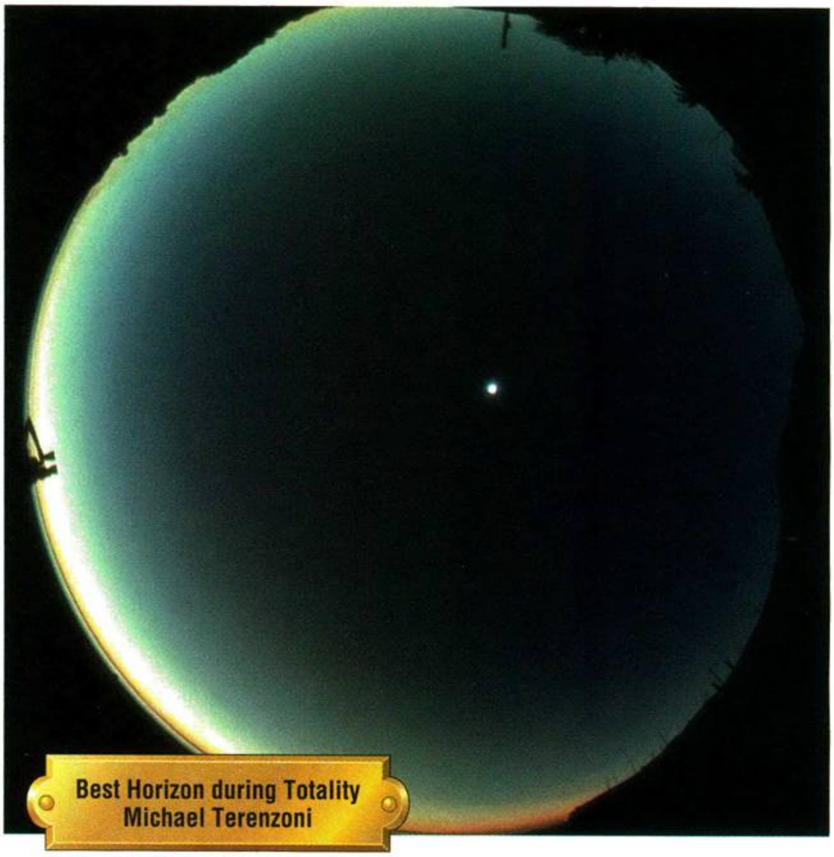
by Richard Talcott

Some people saw four minutes of totality. Some witnessed nearly seven minutes. Others did not even glimpse the Sun because of heavy clouds. But regardless of the view, nearly everyone who traveled to July's "eclipse of the decade" had a story to tell. Residents and eclipse chasers from around the world have regaled our staff with their adventures in exotic locales from Hawaii to Brazil.

But the number of reports we received was nothing compared with the deluge of photographs. At the peak, more than 100 photos and slides per day poured into our offices. What you'll see on these pages is the cream of the crop, the best of the best from the best eclipse in years. What you'll read are the experiences of a few of the millions of people lucky enough to be in the path of totality last July 11.

The Moon's shadow first touched land in America's paradise, Hawaii, but the view proved less than paradisiacal for many. The Sun played hide-and-seek with observers across the Big Island of Hawaii. Elizabeth and Marshall King-Mock were among the lucky ones — they were in and out of clouds, but managed to be out of them when it counted, during totality. Elizabeth recalls: "As the Moon's shadow crept upon us, an eerie twilight provided a unique backdrop for the awesome sight of the Sun's disk completely blocked from our view. The corona seemed to

Gilberto Klar Renner and Luís Antonio Reck de Araujo

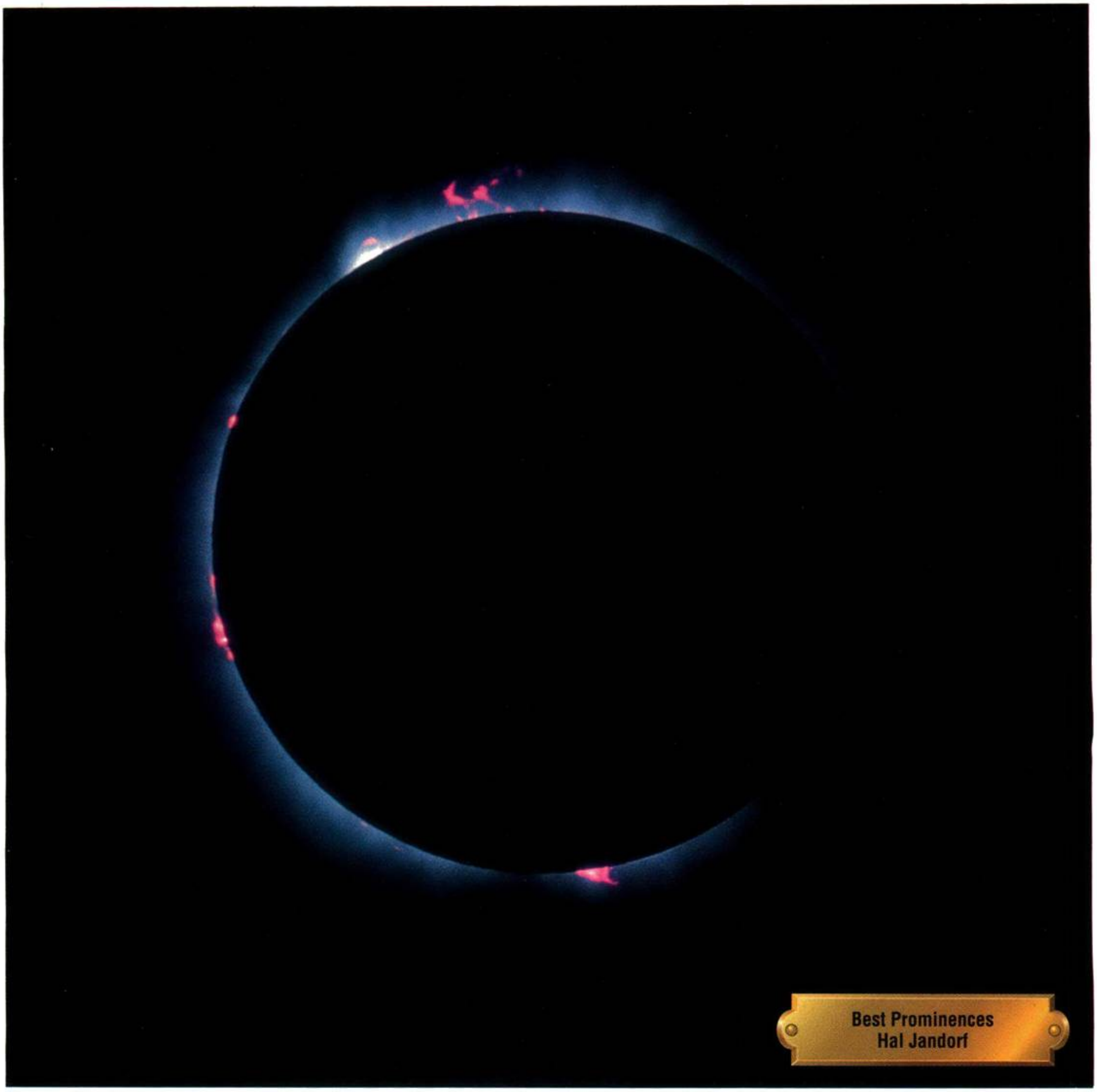


Best Horizon during Totality
Michael Terenzoni

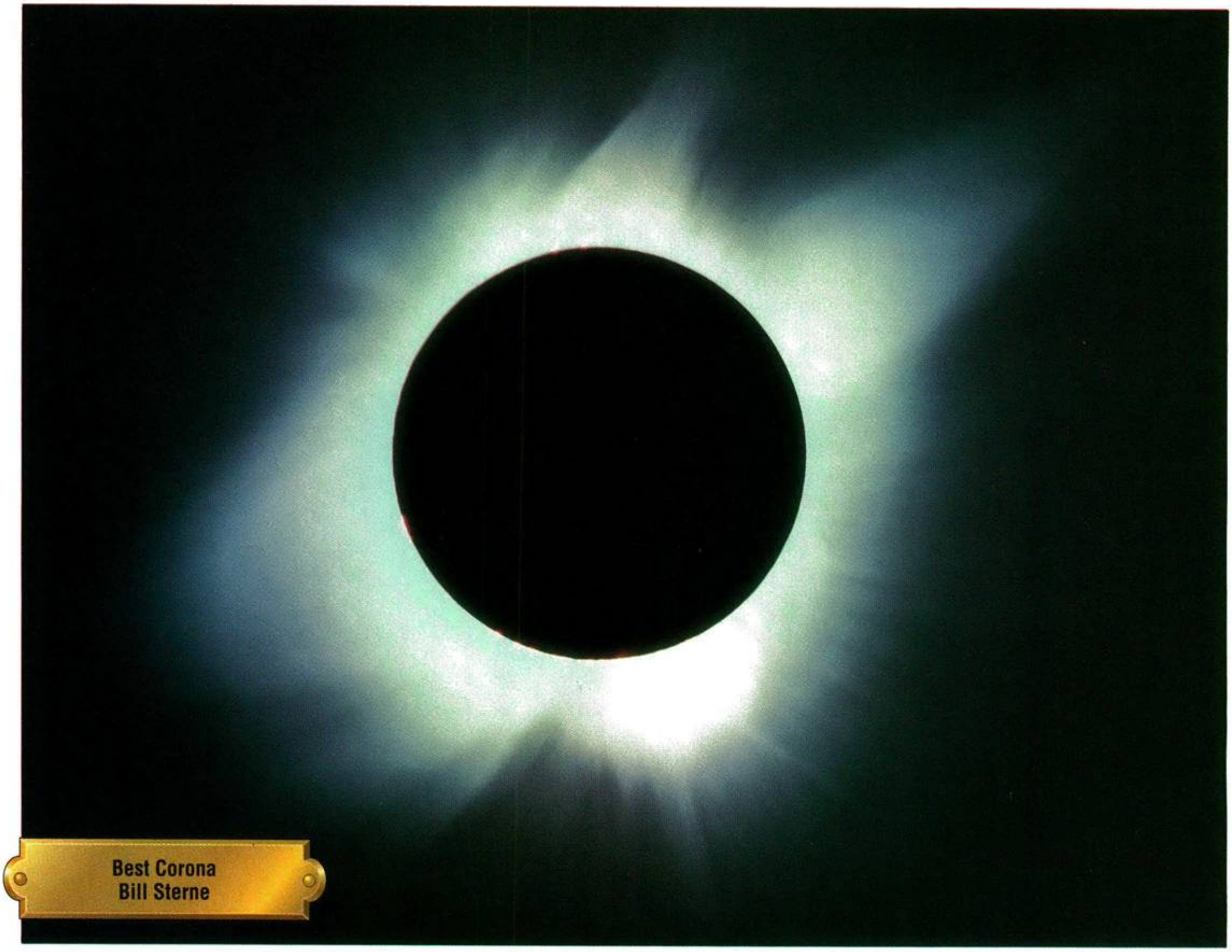
Ralph Merletti

fill more of the sky than it actually did, and even to the naked eye the solar prominences stood out, like ruby colored ribbons, with great intensity. Marshall commented later that the magenta prominences seemed to be bleeding from the bruised Sun. It's no wonder ancient eclipse observers concocted stories of dragons and monsters devouring their precious star."

Some 80 minutes after the Moon's umbra left the Hawaiian Islands, it touched land again under the mostly clear skies of southern Baja California. John Hicks was there to meet it. Hicks and a group of 175 other eclipse chasers were on a one-day mission to Baja. Following a 3 a.m. wake-up call, they flew from Puerto Vallarta on the Mexican mainland to Los Cabos in Baja, and then took a bus north to Santiago.



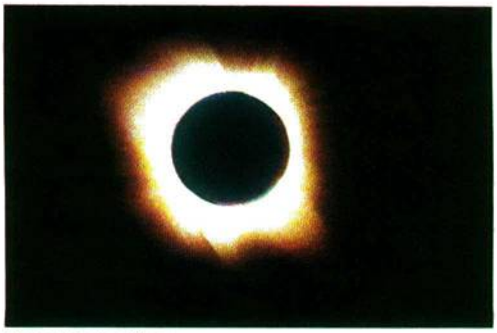
Best Prominences
Hal Jandorf



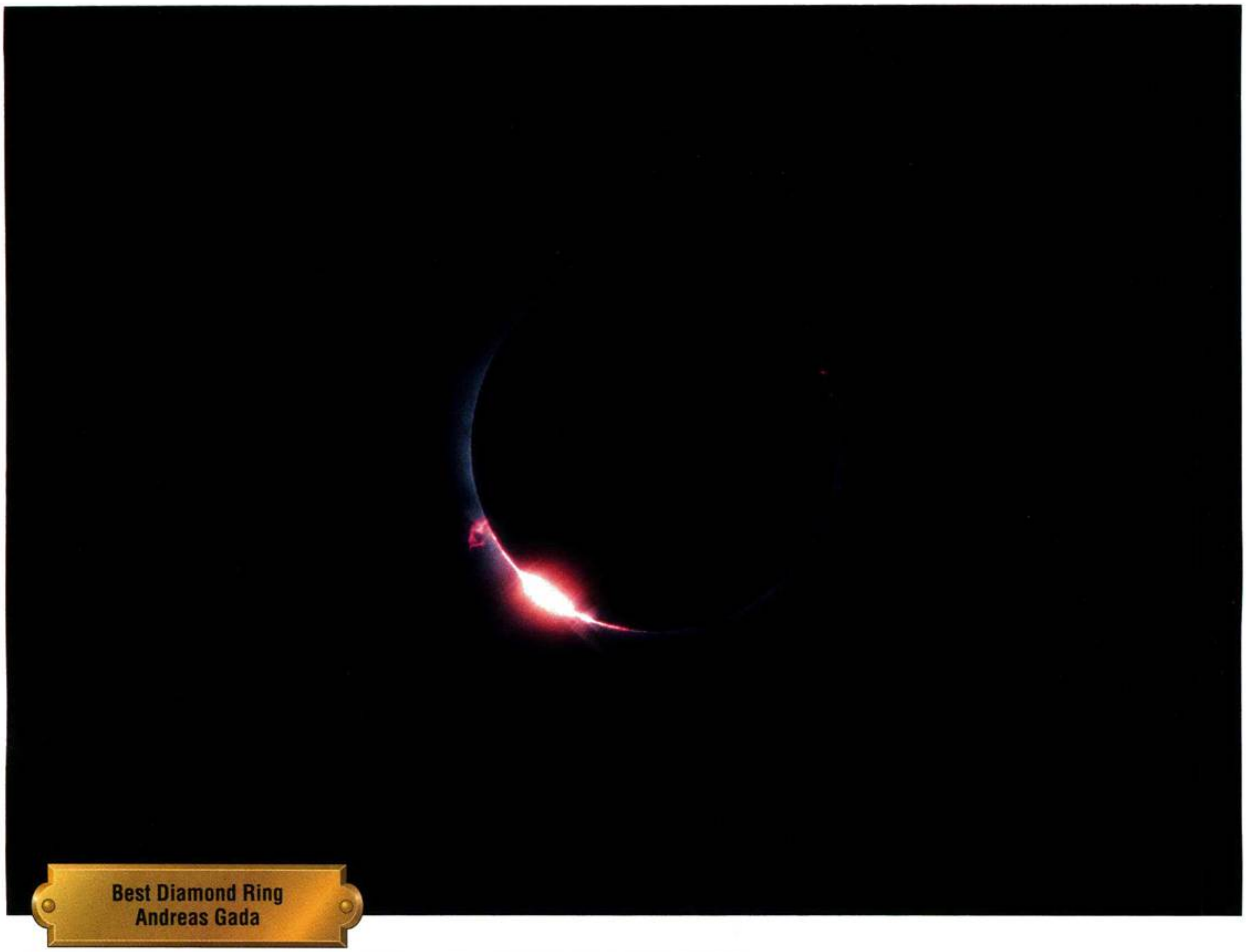
Best Corona
Bill Sterne

Pat Thomas

Elizabeth King-Mock



Eduardo Gomez-Limon



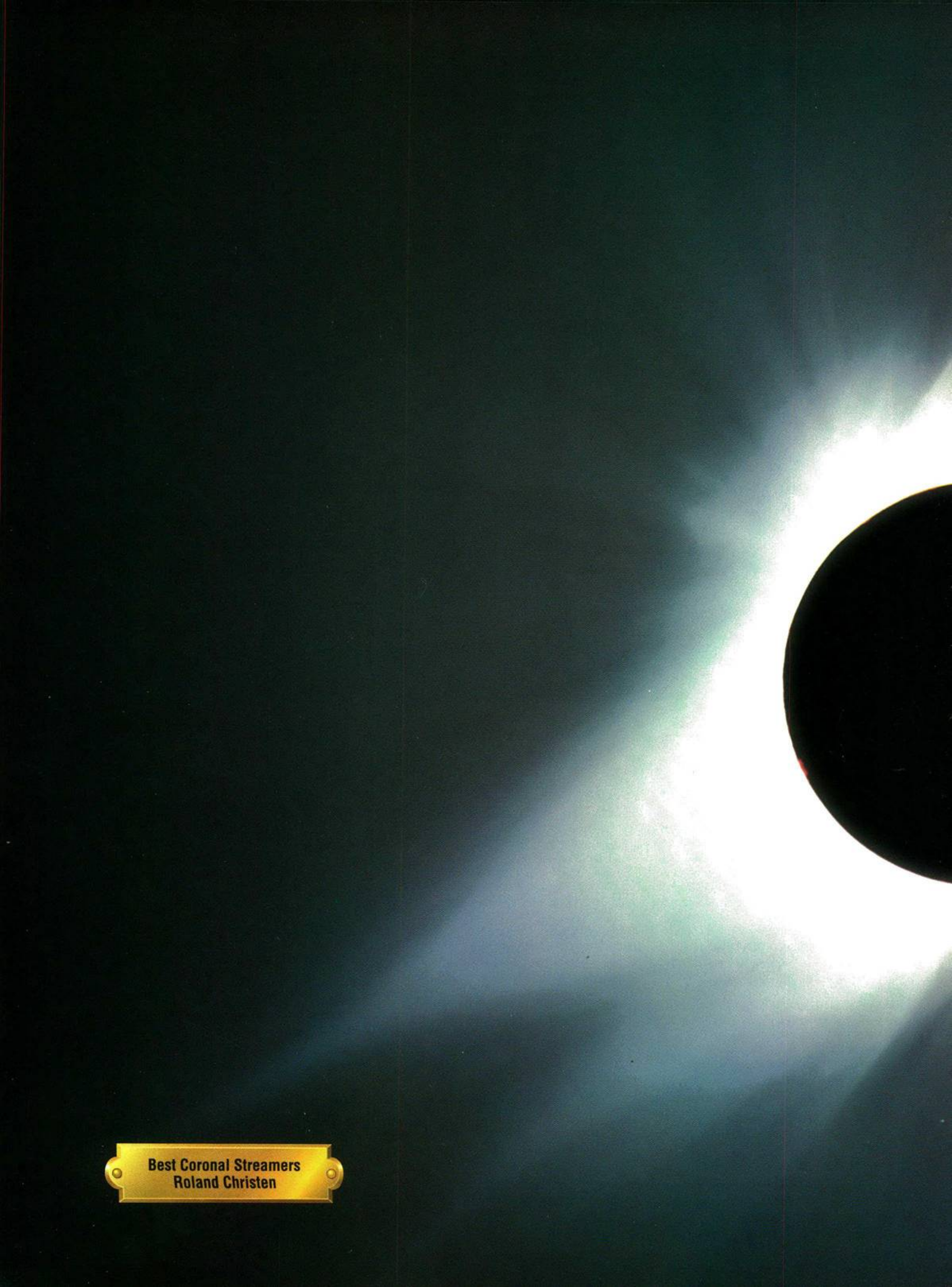
Best Diamond Ring
Andreas Gada

Hicks recalls the group's reaction when the shadow plunged their eclipse site into darkness: "My partners raved and bellowed all kinds of mindless words, trying to describe the undescribable. I began to laugh, but I don't know why." Of all the eclipse sights, Hicks most remembers the beautiful prominences — "lizard-tongues of soft pink leaping out around the now dark limb of the Sun."

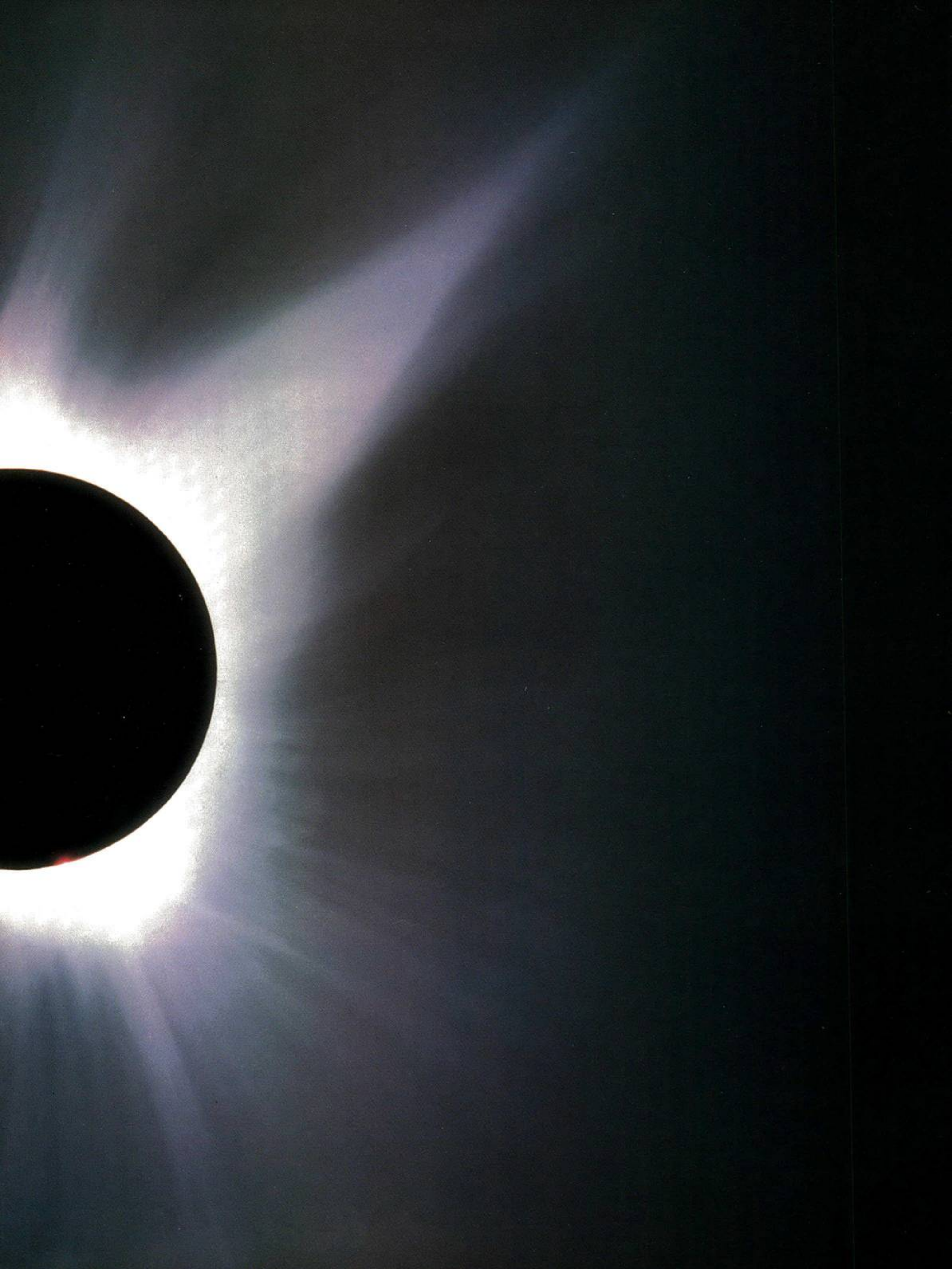
The Moon's shadow next traversed the Sea of Cortez — where thousands of people witnessed totality from the decks of cruise ships — and then plunged into mainland Mexico. Although many people journeyed to the west coast of Mexico to see the eclipse, few traveled to inland Mexico to see the next stop on the shadow's tour of the Western Hemisphere — most were scared away by poor weather prospects. But John Franch is glad he bucked the odds. He chose Mexico City, a

HOW THEY DID IT

Pages 32-33: Jeff Schroeder, 4-inch f/15 refractor, Kodachrome 64 film, 1/60-second exposure. **Page 34, left:** Gilberto Klar Renner and Luís Antonio Reck de Araujo, 50mm f/1.4 lens, Fuji 400 film, 1/8-second exposure, from Gurupí, Brazil; **right:** Michael Terenzoni, 8mm f/2.8 fisheye lens, Kodachrome 64 film, 1-second exposure; **bottom:** Ralph Merletti, f/11 lens, 1/1000-second exposure. **Page 35:** Hal Jandorf, 3.7-inch telescope at f/14, Fujichrome 100 film, 1/250-second exposure. **Page 36, top:** Bill Sterne, 1250mm f/10 lens, Ektar PHR120 (ASA 25) film, 2-second exposure; **bottom left:** Pat Thomas, 5-inch f/5 lens stopped to f/8, Kodacolor Gold 100 film, 1/60-second exposure; **middle right:** Elizabeth King-Mock, 70mm f/3 lens, Fuji 100 film, 1/60-second exposure; **bottom right:** Eduardo Gomez-Limon, video still. **Page 37:** Andreas Gada, 6-inch f/6 Newtonian, Kodachrome 64 film, 1/1000-second exposure. **Pages 38-39:** Roland Christen, StarFire 130EDT f/8 telescope with radial gradient neutral density filter, Ektar 25 film, 2-second exposure. **Page 40, top:** Ronald and Helen Kosler, Nikon one-touch camera; **middle above:** Andreas Gada, 6-inch f/6 Newtonian, Kodachrome 64 film, 1/2-second exposure; **middle left:** Chester Roistacher, 200mm lens, ASA 200 film; **middle right:** Bill and Sally Fletcher, 8-inch f/4.5 reflector, Ektar 25 film; **bottom:** Carter Roberts, 135mm lens, Fuji Velvia sheet film, photos taken every 6 minutes, all 1/50-second exposures. **Page 41, top left:** Brenda Culbertson, 8-inch f/10 SCT, Kodak Gold 400 film, 1/500-second exposure; **middle left:** John Gianforte, 8-inch f/10 SCT, Kodachrome 64 film, 1/250-second exposure; **top right and middle right:** Ron Dilulio, video stills; **center:** Jeff and João Wang, 200mm f/8 lens, Ektachrome 100 Plus film, 1/60-second exposure, from Jauaés, Brazil; **bottom:** Joseph Rothchild, 35mm f/3.5 lens, Kodachrome 64 film, 1-second exposure. **Page 42, top:** Rob Scott, 130mm f/8 lens, Ektar 25 film, 1/250-second exposure; **bottom:** Terry Piotrowski photo of San Francisco Bay Area Eclipse Chasers and Ernie Piini's telescope. **Page 43, top left:** Spencer Rackley IV, 7.5mm f/4 fisheye lens, Fujichrome 50 film, 1/1000 second, on the cruise ship *Jubilee*; **top right:** Pat and Kent Haroz; **middle:** Mikael Reardon, 80mm twin lens, Ektachrome Professional 100 film, photos taken every 5 minutes, partial phases — 1/125-second exposures at f/22, totality — 1-second exposure at f/3.5; **bottom:** Nobutaka Magome, 500mm f/7.7 lens with holographic grating, Fuji 400 film.



Best Coronal Streamers
Roland Christen

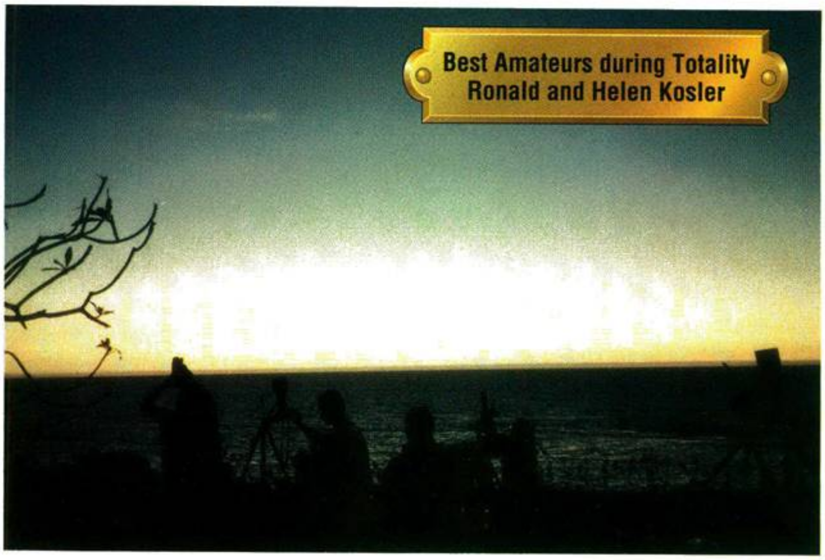


sprawling metropolis of some 18 million people, despite its thick smog and almost daily rains in July. "I journeyed there for the sheer atmosphere of the place," says Franch. Franch set up his 4-inch reflector at noon on the southwest side of the *zócalo* of Mexico City — the largest square in the Western Hemisphere — and was soon surrounded by a crowd wanting to view the projected image of the Sun. Unfortunately, the clouds did not stay away. "As the sky darkened," notes Franch, "the everpresent cumulus clouds thickened. Only five minutes before totality, the Sun suffered a premature eclipse.

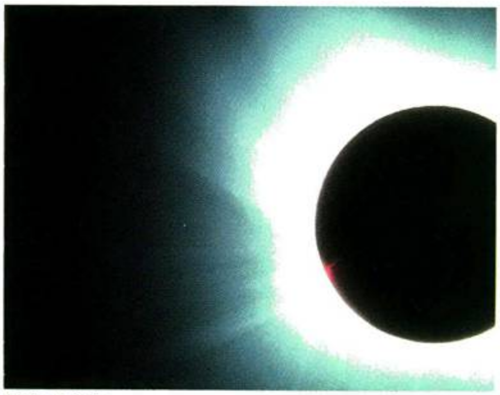
"I broke away from the crowd around my telescope as totality set in at 1:24 p.m. Sodium lights ringing the *zócalo* flipped on, tinting everything an eerie orange. Flocks of pigeons flapped in erratic circles; people, too, seemed no less dazed. Minutes passed, still no Sun. While soaking up my terrestrial surroundings, I turned skyward. Wow! Behold, the totally eclipsed Sun! The black hole of the Moon was wreathed in a pearly coronal halo and behind its western limb leaped a brilliant red prominence. Five seconds later this vision of heaven was gone, conquered by the clouds, but it was the most memorable five seconds of my life."

The Moon's shadow continued southward through Mexico and on into Central and South America, where the skies sometimes cooperated and sometimes did not. David Dempsey, who lives in Panama, was one of the lucky ones.

"Trucks and cars bearing acquaintances from the city pulled up by my cabin on a lovely, lonely beach, deep in the Azuero Peninsula. As beer cans popped open, rock music drowned out the throb of the sea. When the firecrackers materialized, I knew it was time to retreat to my carefully chosen eclipse site in the nearby hills. I made my escape, waving encouragingly to three Smithsonian biologists with car problems, whose eyes bespoke the despair of serious people



Best Amateurs during Totality
Ronald and Helen Kosler

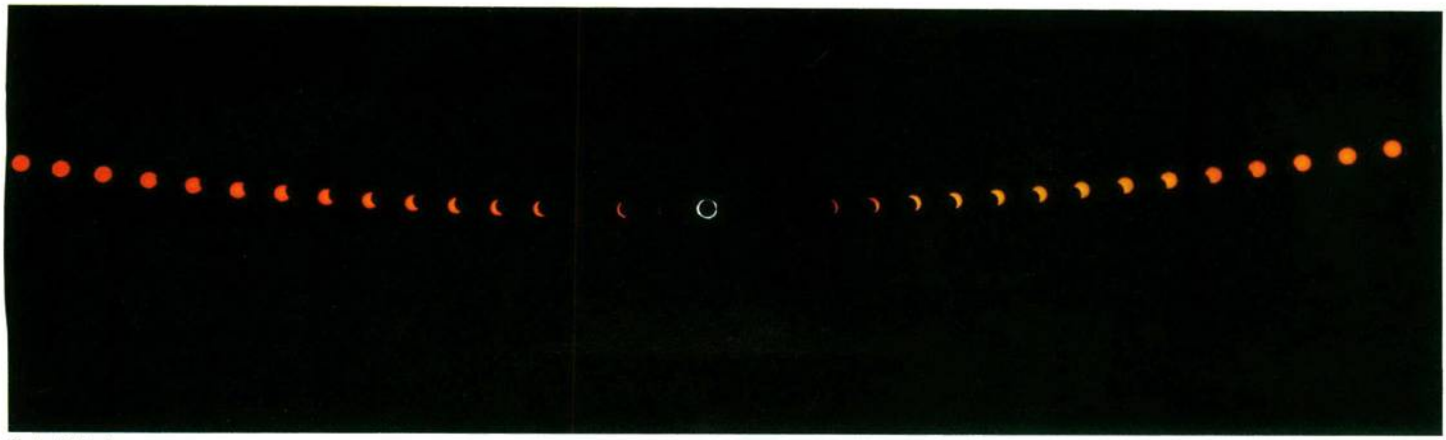


Delta Geminorum is the point of light just left of the Sun's corona. During totality, it lay less than one solar diameter from the eclipsed Sun.

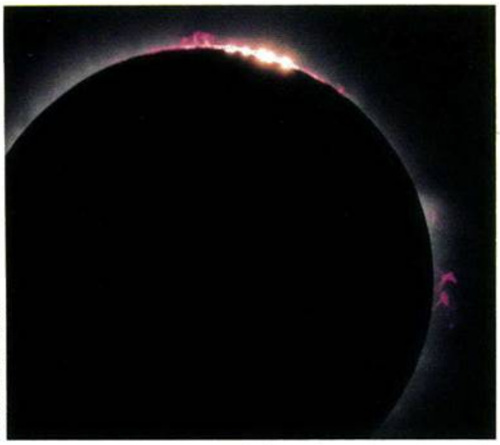
Andreas Gada

Chester Roistacher

Bill and Sally Fletcher

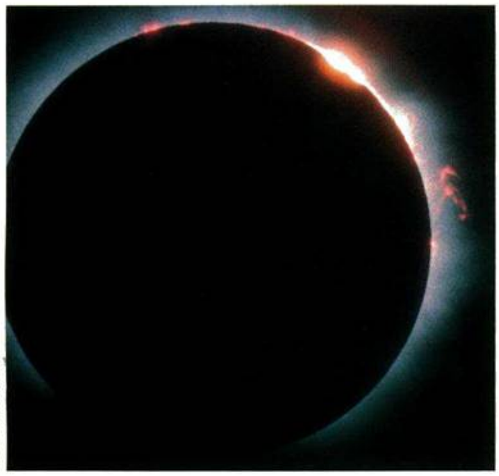


Carter Roberts



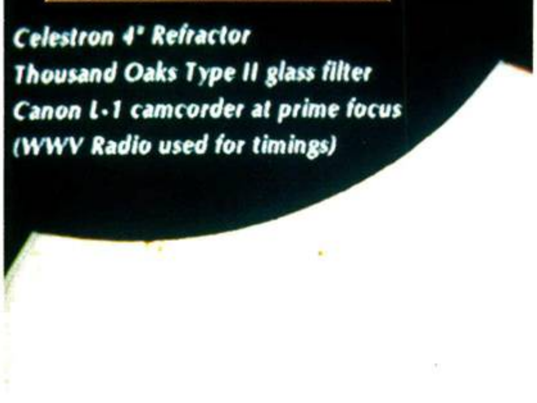
Brenda Culbertson

Baily's beads appear at different locations along the Moon's limb from different observing sites on Earth. From south of the centerline (above), the beads appear far from the bright prominence at 3 o'clock. From north (below), they are much closer.



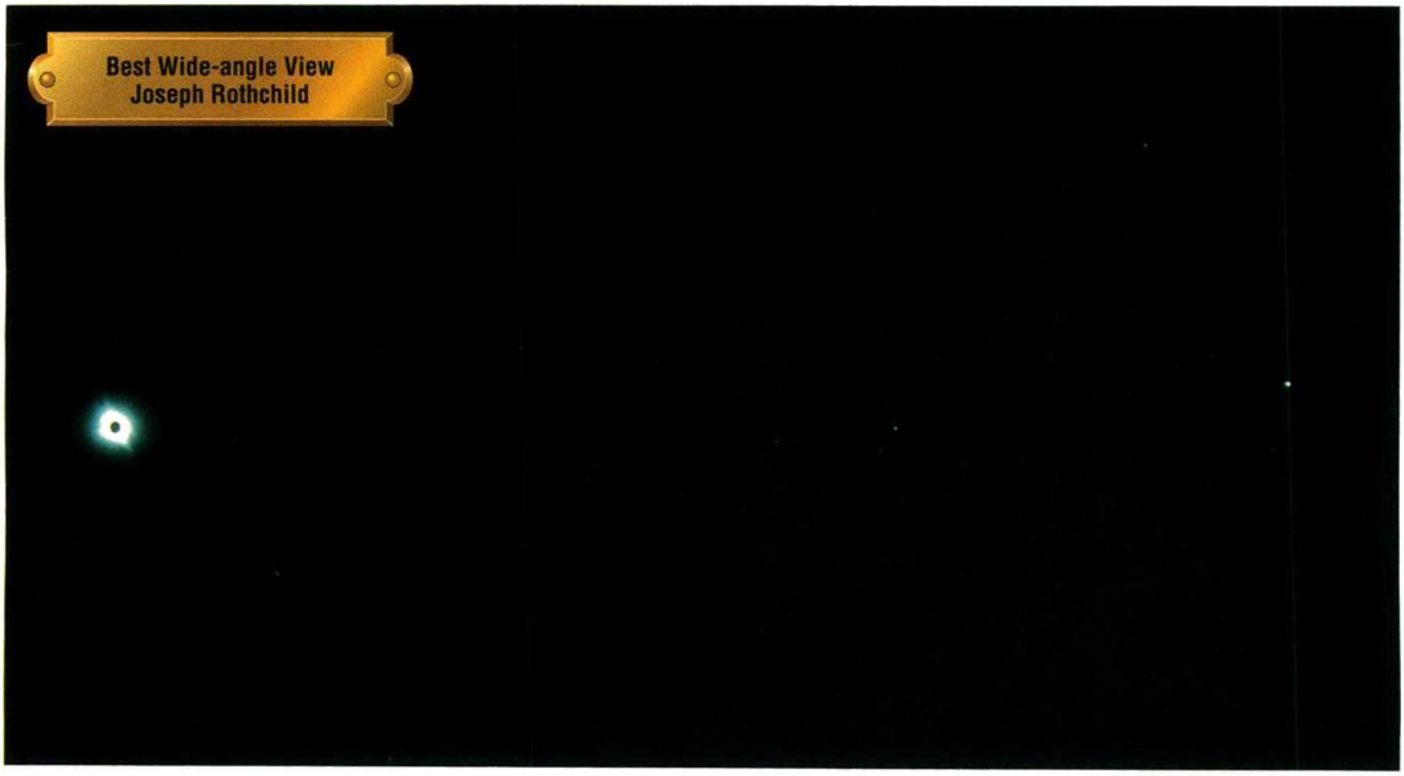
John Gianforte

Best Video
Ron Dilulio

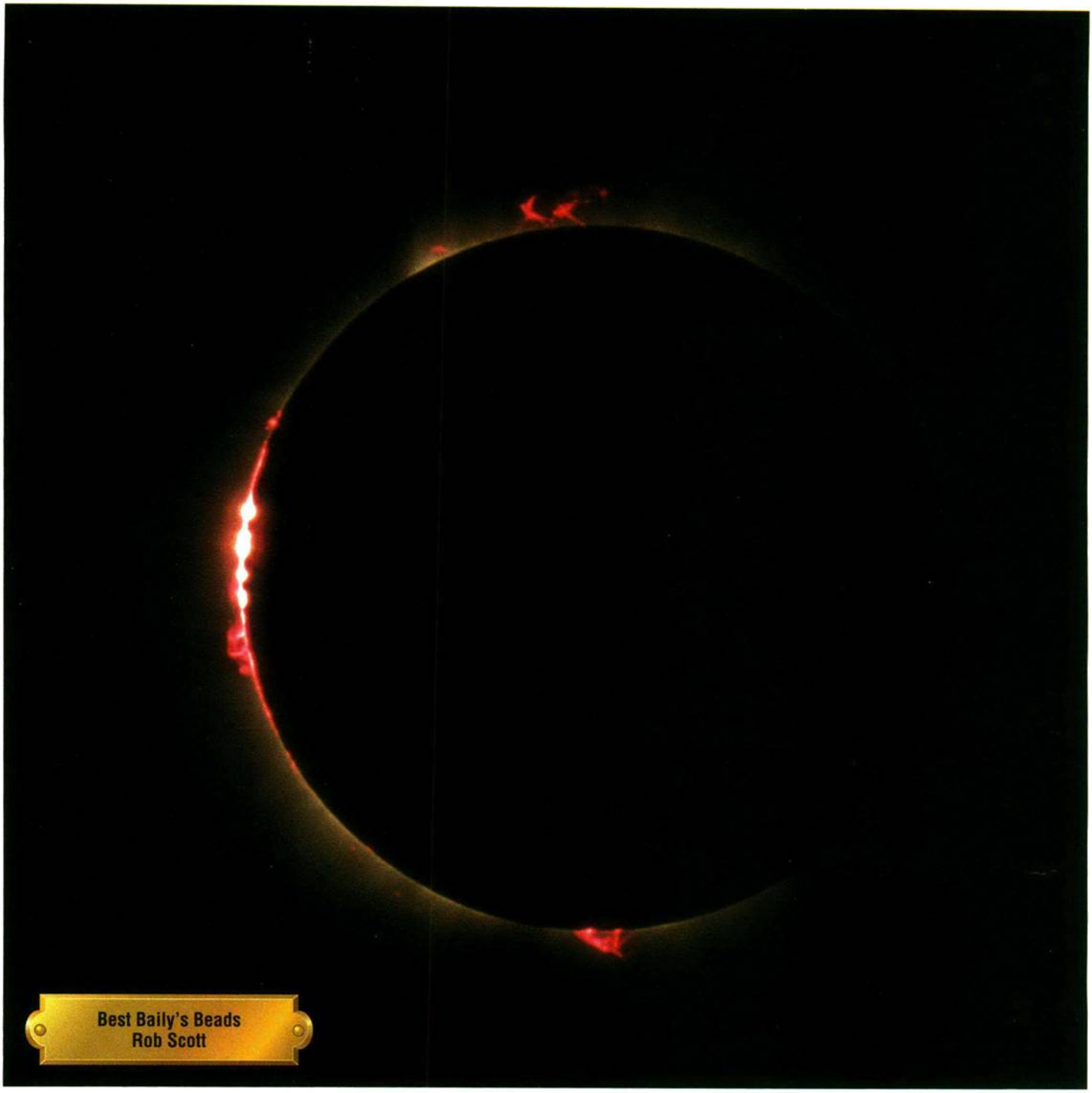


Celestron 4" Refractor
Thousand Oaks Type II glass filter
Canon L-1 camcorder at prime focus
(WWV Radio used for timings)

Jeff and Joãno Wang



Best Wide-angle View
Joseph Rothchild



Best Baily's Beads
Rob Scott

Best Eclipse Preparations
Terry Piotrowski

A flash spectrum of the Sun's chromosphere (right) reveals the makeup and physical conditions in this part of the solar atmosphere.

Best Group Picture
Spencer Rackley IV

Pat and Kent Haroz

Crescent Suns dapple the rump of this eclipse watcher.

doomed to share the experience of a lifetime with a group of forty-year-old teenagers.

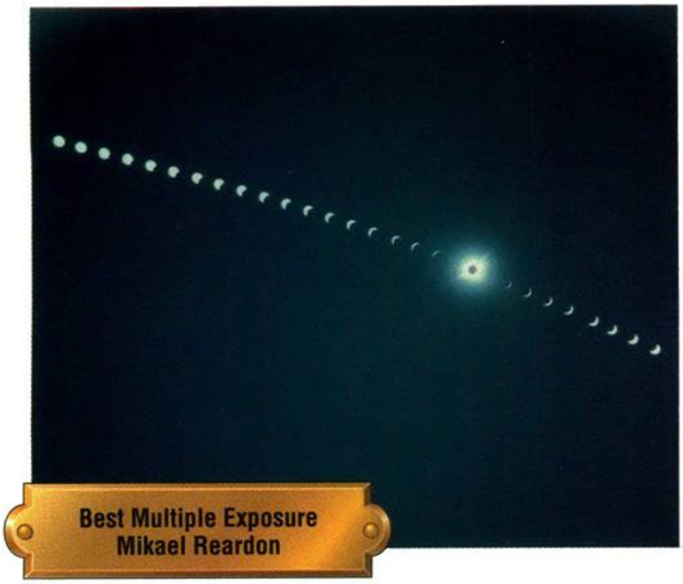
"But shortly after first contact, the wind changed direction and clouds began to move in. I looked down at the coastline and saw a veil of cloud, broken only by one tawny half-circle of sunlight on the beach. As the Sun's crescent grew smaller, a troop of howler monkeys in the surrounding jungle mistook the false dusk for bedtime and struck up their customary deep baying lullaby.

"When I glanced at the coast again, I noted that the same spot was still in sunlight. I quickly packed my gear and made a wild dash to the illuminated patch of beach. The coast was clear, and luckily it stayed that way. When the diamond ring faded, I pressed the start button of my stopwatch, intending to time totality.

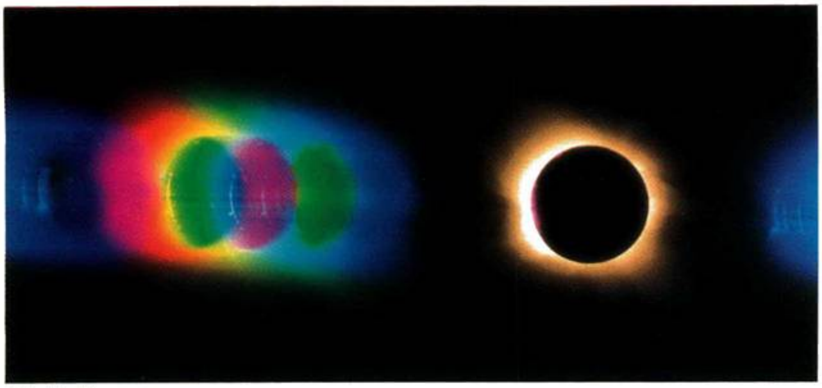
"Nothing prepared me for the loveliness of the corona. Its blue-white glow seemed to flicker softly as I gazed upon the Sun for the first time in darkness. In the daytime, the Sun's glare makes our star appear rather large. There in the dark that afternoon, I saw that it is, in fact, very small.

"Totality seemed to last forever. When the first sliver of Sun finally reappeared, the world seemed to brighten far more rapidly than it had darkened. I stood there motionless, marveling, long into daylight. Two days later, I remembered to turn off the stopwatch."

For some people, like David Dempsey, time stood still during totality. For others, totality was over almost before it started. Either way, the memory of the eclipse lasts a lifetime. For those who saw this eclipse, the photographs here can help you relive the event. For those who missed it, they may provide a hint of the experience. But nothing compares to seeing a total eclipse for yourself. Don't let the next good opportunity pass you by. □



Best Multiple Exposure
Mikael Reardon



Nobutaka Magome

WILL THE LION ROAR AGAIN?

Every November observers remember the spectacular Leonid meteor storm of 1966. What are the chances that it will happen again?

by Ken Croswell

If you ever wanted to prove the experts wrong, the place to be was the western United States on the night of November 16-17, 1966. Meteor experts said nothing would happen — the great Leonid meteor storm was dead.

The experts, of course, knew all the facts. Though the Leonids can provide spectacular displays every 33 or 34 years, they are normally only a weak November shower. Furthermore, a century had passed since the Leonids last stormed over America. There was no storm in 1899 or 1933, and the experts claimed that the meteor stream producing the Leonids had shifted in space so that Earth no longer ran into its dense core.

In 1998 or 1999, we may see the most spectacular Leonid display ever.

Bright Lights, Big Storm

It is midnight and the Lion is rising. Above the northeastern horizon, the huge head of Leo appears and then, a few minutes later, Leo's blue-white heart, the bright star Regulus. Overhead, an occasional meteor flashes across the sky.

Leo rises higher, Regulus twinkles brightly, but the shower remains weak. At 2 a.m., meteors are falling at the rate of just 30 an hour. The meteors are fast, many are bright, and several are green or blue. You take notes on them all — their colors, their magnitudes, their locations. The meteors indeed radiate from Leo's head, but their number is so low that you begin to fear that the experts were right.

By 3 a.m. Leo is high in the east, and at last the meteors start to pick up — one a minute, then two a minute, then three a minute. A sense of excitement builds within you. Could a meteor storm be coming, one to rival the great displays of 1833 and 1866? Several green fireballs race across the sky, silently exploding with a white light. The shower intensifies. There must be a dozen or more meteors every minute, and you give up trying to record them.

Around 4:30, the shower becomes a full-fledged storm. Hundreds, then thousands of meteors shoot across the sky. You can barely estimate their number. Five per second? Ten? Twenty? You work out the numbers in your head: 20 x 60 x 60 = 72,000 meteors an hour!

By 5 a.m., the Lion is high overhead and it is raining meteors. They flash across the sky rapidly and you clutch the ground for support. As when driving a car on a snowy night, you feel yourself hurtling through space at top speed — smashing into the dense cloud of particles through which Earth is plowing.

The storm lasts an hour, then dies down. As dawn arrives and clouds in the east turn red and purple, the Leonids are still producing several meteors a minute. By sunrise you are exhausted but happy. Unlike the experts, who stayed asleep all night, you have witnessed the greatest meteor storm of the 20th century.

Or maybe not.

Before this century ends, the Leonids may stage a return engagement that equals or even exceeds their incredible performance in 1966. Conditions in 1998 and 1999 are especially good. But will it really happen? Will the Lion roar back to life?

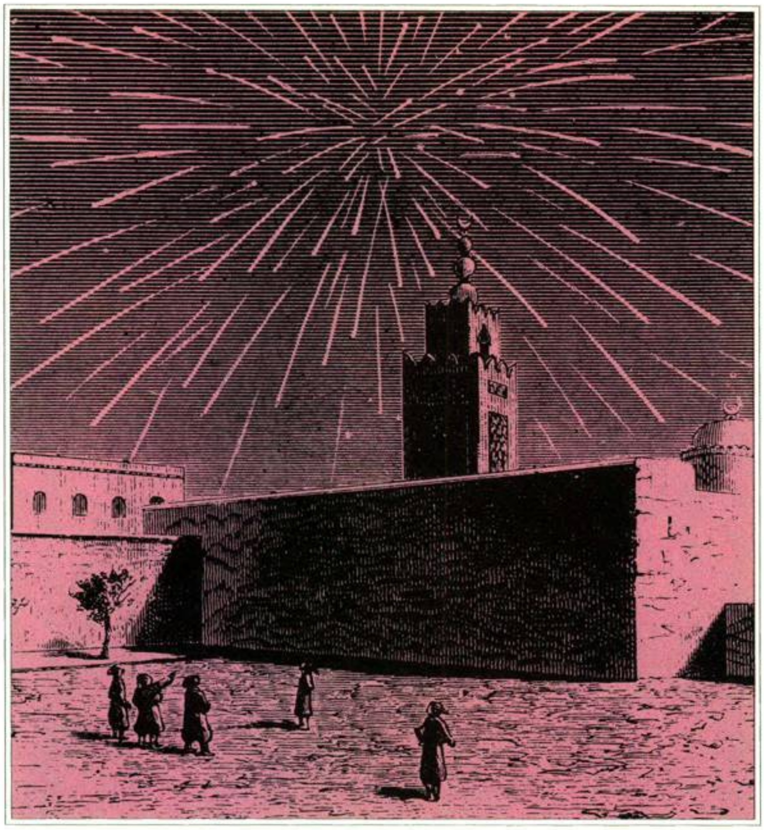
Interplanetary Blizzard

In a normal year, the Leonid shower is nothing to get excited about. The meteors do tend to be bright, with colors of white, green, or blue, and many leave trails. But at their peak around November 17, the Leonids produce only 10 or 15 meteors per hour. The Perseids of August and the Geminids of December offer far more active displays.

Meteor showers occur when Earth runs headlong into a stream of tiny particles shed by a comet and still traveling in its orbit. The Leonid meteors arise from Comet Tempel-Tuttle, which revolves around the Sun every 33 years in a very elongated orbit. At its closest point to the Sun, the comet passes just inside Earth's orbit; at its farthest, the comet journeys out to the orbit of distant Uranus.

Like a truck spewing exhaust, Comet Tempel-Tuttle leaves a trail of dusty debris along its path, and like the comet itself, every particle in the stream orbits the Sun with a 33-year period. Each November, our planet hurtles through this debris trail and we see a meteor shower. Both the debris and Earth pursue separate paths around the Sun, but the geometry of their meeting ensures that the meteors always appear to come from the direction of the zodiacal constellation Leo the Lion, hence their name. The meteors actually travel on parallel paths, but perspective makes them

The 1799 Leonid storm was a harbinger of greater storms to come — but astronomers at the time didn't recognize it for what it was.



look as if they are flying out from a single point on the sky, just as railroad tracks appear to converge in the distance.

The particles (called meteoroids) that comprise the Leonid meteor stream do not spread uniformly along the comet's orbit. This makes the Leonid stream unlike most other streams. For example, the meteor streams responsible for the Perseids and Geminids are so uniform that they provide good, reliable showers every year. But the meteoroids in the Leonid meteor stream congregate around the parent comet, Tempel-Tuttle, so spectacular storms can occur only when the comet is near. It is due back in 1998.

Leonids are swift. They smash into Earth's atmosphere at 70 kilometers per second, faster than meteors from any other major shower. The reason is that like the comet that creates them, Leonid meteoroids orbit the Sun backward, or in a retrograde direction. They therefore collide head-on with Earth. In contrast, Geminid meteoroids orbit the Sun in the same direction we do and encounter Earth at only 35 kilometers per second.

By 1966 the experts thought Leonid "storms" were dead and gone. Boy, were they wrong.

A retrograde meteor stream like the Leonids shifts in space so that the shower appears slightly later each year. The Leonids currently peak on either November 17 or November 18, depending on the vagaries of the calendar. In the future, however, the Leonids will occur later and later in November. In past centuries, the Leonids arrived in early November, and during the Middle Ages they occurred in October.

Like driving into a snowstorm, viewing a rich display shows unmistakably that the on-rushing meteors all come from one point in space.

The Storms of Yesteryear?

But did the astronomers of yesteryear even know of meteor showers? It's a good question. Medieval philosophers certainly knew about meteors but thought they were atmospheric features rather than celestial phenomena. (Notice how we still call the study of the atmosphere "meteorology.") The notion of meteors being atmospheric derived originally from Aristotle, who believed that the atmosphere was variable, while the heavens were changeless. Even in post-Renaissance astronomy, however, no one recognized an annual meteor shower in November, much less a meteor radiant in Leo.

All that changed shortly before dawn on November 13, 1833. A few hours prior to sunrise on that date, tens of thousands of meteors blazed across the sky of eastern North America. People woke their neighbors to tell of the spectacle, while the fireballs themselves woke other people, as bright flashes lit up dark bedrooms with eerie moving lights. A few people proclaimed that the end of the world was near.

The 1833 storm didn't mark the end of the world, but it *did* herald the start of modern meteor astronomy. Because of the great numbers of meteors, anyone could see that they radiated outward from a point among the stars near Leo's head. Astronomers thus recognized that the meteoroids came from space and were approaching Earth on nearly parallel orbits. The 1833 storm over North America was brief, and it had not been seen from Europe. But a similar storm had occurred the previous November in Europe and the Middle East. Alerted to the clues, astronomers looked further back and found there had also been a meteor storm in November 1799 — 33 years before the European storm of 1832. Finally, astronomers realized the truth: each November Earth runs into a cloud of particles.

After 1833, the Leonids settled down, although astronomers continued to note modest displays every November. The interval between the 1799 and 1832-1833 storms led astronomers to deduce that the main clump of Leonid meteoroids was orbiting the Sun every 33 or 34 years; simple arithmetic pointed to a major storm in 1866. That storm appeared on schedule, as did others in 1867 and 1868. But these storms did not equal the 1833 event — they produced "only" a few thousand meteors per hour.

Once again, the annual Leonid displays soon returned to modest activity. But as the end of the century approached, astronomers looked ahead with anticipation. In 1898, the Leonids produced greater-than-usual activity — 50 to 100 meteors an hour — which astronomers took as a sure sign that a big storm was in the offing. Confidently they predicted that meteors would storm across the sky in 1899. Newspapers publicized the predictions and thousands of people gazed skyward, hoping to experience for themselves the excitement of 1833 and 1866.

But nothing happened.

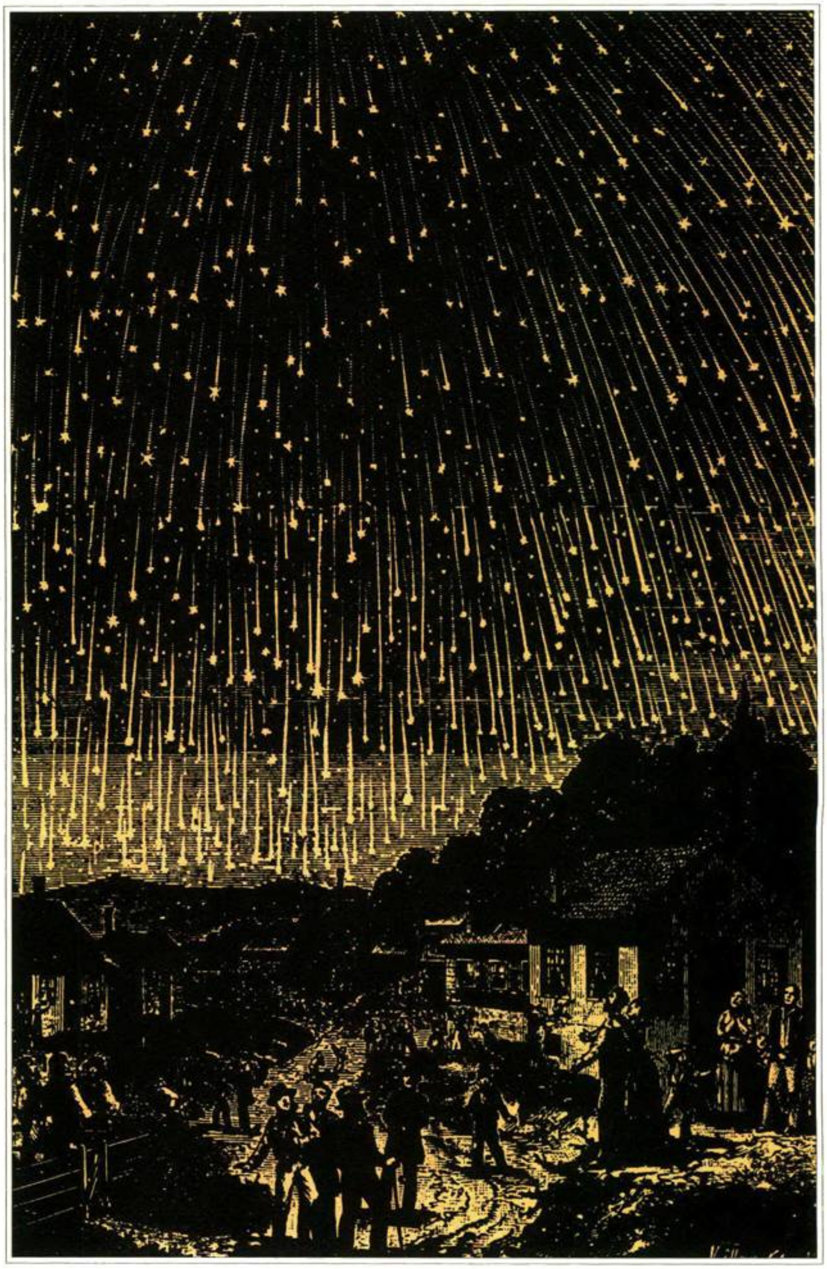
The promised storm turned out to be a mere drizzle of only some 40 meteors an hour. "The failure of the Leonids to return in 1899 was the worst blow ever suffered by astronomy in the eyes of the public," wrote meteor astronomer Charles Olivier years later. The following year, 1900, was also a disappointment. The true peak — which was very small — came in 1901, but by then few people could be bothered to look. Worse still, the Leonids failed to come through in 1932 and 1933. In 1932, they produced only a couple hundred meteors an hour — a good shower, but nothing more.

All signs indicated that the great Leonid meteor storms were dead. Astronomers argued that because the Leonid meteor stream stretches to Uranus, it had been perturbed by the gravity of Jupiter and Saturn. As a result, they said, the small dense core of particles responsible for the mighty storms no longer passed through Earth's orbit. Wrote astronomer Bernard Lovell in the 1950s, "It now seems certain that the main part of the Leonid orbit has been removed from the Earth's orbit by successive perturbations, and the recurrence of the tremendous meteoric storms of the Leonids in the future seems unlikely."

But the experts were wrong. Although the Leonid displays of the 1940s and 1950s produced just 10 or 15 meteors an hour, the shower began to revive in the early 1960s. In 1961, the Leonids yielded 50 meteors an hour, then in 1962 and 1963, the rate dropped to 15 to 20 an hour. But it rose in 1964 to 30 an hour and again in 1965 to around 100 an hour.

And then came 1966. By now professional meteor astronomers weren't expecting much. Yet the Lion was not dead — it had merely been slumbering. The Leonids roared back to life with ferocity, sending out as many as 150,000 meteors an hour over the western United States. Unfortunately, the more populous eastern United States did not see the storm, for dawn was well underway there when the storm hit. Bright flashes appeared in the dawn sky, however, a sign that something spectacular was happening overhead.

After 1966, the Leonids produced fine showers (although no storms) for several years; then they settled back into their familiar pattern of 10 to 15 meteors an hour. In recent years, however, the Leonids have grown somewhat more active, perhaps heralding the comet's return.



A rich display of Leonids in 1833 surprised — and thoroughly frightened — many onlookers, but it led astronomers to discover what causes meteor showers.

Comet Tempel-Tuttle

To make sense out of the tangled history of the Leonids — and to predict their future more accurately — we must examine the comet that produces them, Tempel-Tuttle. Like most short-period comets, Tempel-Tuttle has an orbit that varies over the centuries. But right now it is in the best possible position to produce Leonid storms.

European astronomer Wilhelm Tempel discovered the comet on December 19, 1865, eleven months before the 1866 Leonid storm. American astronomer Horace Tuttle independently discovered the comet in early January 1866. Like the Leonids themselves, the comet had a period of about 33 years.

After the 1866 storm, several astronomers noted the similarity between the Leonids' orbit and the comet's and suggested that the comet was the source. The comet was not seen in 1899 or 1933, but astronomers did recover it in 1965. It reached perihelion in April 1965, 19 months before the great storm of 1966.

The orbit of Comet Tempel-Tuttle varies slightly over the years because of gravitational perturbations by the planets. At present the comet has a period of 33.2 years and at perihelion comes within 0.98 astronomical unit of the Sun. Since one AU is the mean distance from the Sun to Earth, the comet at perihelion passes slightly inside Earth's orbit.

Unfortunately, the orbit of both the comet and the meteor stream tilts only 18° to the plane of Earth's orbit. This means the comet's orbit also lies close to the orbits of Jupiter and Saturn, two massive planets whose gravity can perturb the path of the comet and meteoroids. In contrast, the reliable Perseid shower, which people have been observing for almost two thousand years, arises from a meteor stream that makes nearly a right angle with Earth's orbit and consequently never comes near the influence of Jupiter and Saturn.

Despite the perturbations, Leonid storms have nevertheless occurred for at least the last thousand years. In 1981, Donald Yeomans of the Jet Propulsion Laboratory analyzed past records of meteor activity in an attempt to identify Leonid storms and, from that, to map out the distribution of dust around the comet. He sought to find which conditions are most likely to produce meteor storms and to predict future prospects for the Leonids.

Modern meteor astronomy was born in the fantastically rich Leonid meteor shower of 1833.

Yeomans found that over the last thousand years, while the Leonids have the potential to storm every 33 or 34 years, they don't always do so. His primary conclusion was that chances for a meteor storm are best when Earth passes through that part of the stream which lies outside and behind the comet's orbit. Yeomans thinks that radiation pressure from the Sun continually drives dust away from the comet. Thus when Earth passes near the comet and just outside its orbit, we have the highest chance of careening through the densest part of the dust cloud.

This overall situation has prevailed since 1666, and several meteor storms have occurred during this time. According to Yeomans, from 1266 to 1499, Earth always passed through particles lying inside the comet's orbit; during this time only one storm was noted — in 1366 — which indicates that less dust lies inside the comet's orbit.

If Yeomans' orbit calculations are right, the next Leonid "season" places us in the best seats in the house. We will again be passing through particles outside the comet's orbit — just as we did in 1833, 1866, and 1966. Still, there's no guarantee of a storm, for the same conditions prevailed in 1899 and 1933 and little happened.

Which year will be best? Yeomans' work indicates that the years before perihelion — that is, from now until 1997 — will probably not produce storms. In these years, we are ahead of the comet and pass through less dust. Nevertheless, storms *can* occur. For example, the 1799 storm struck when we were still ahead of the comet.

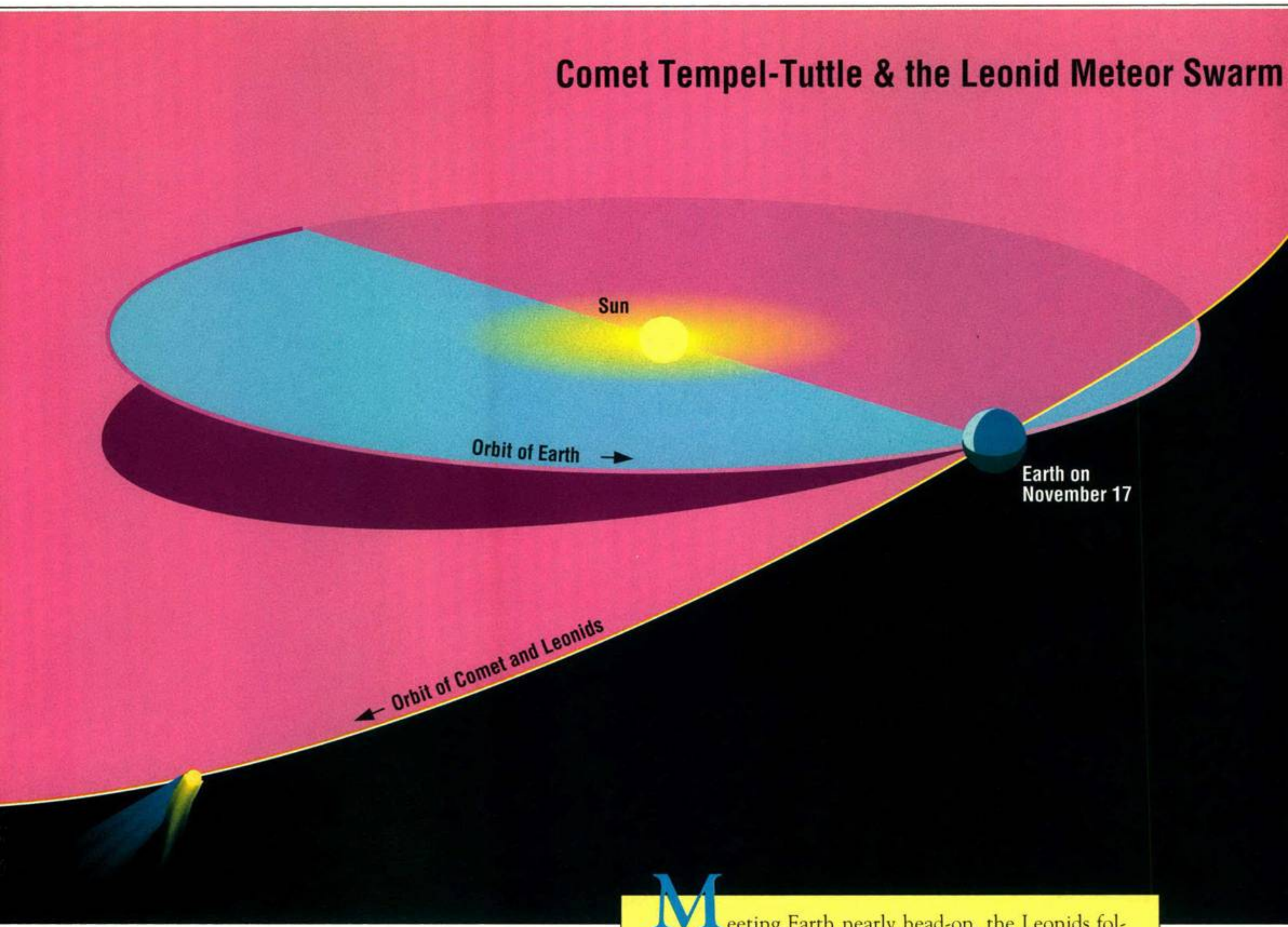
The ideal years, though, are those after Tempel-Tuttle reaches perihelion, when we pass behind the comet and through the region where most of the dust lies. In the upcoming Leonid season, 1998 and 1999 are ideal, but storms could also occur in 2000 or even 2001. Leonids can storm as late as four years after the comet reaches perihelion.

An Extended "Meteor-logical" Forecast

The only safe prediction is that the Leonids are notoriously unpredictable! They have fooled astronomers before and they will probably do so again. Don't listen to anyone who promises you a "guaranteed" Leonid storm — there's no such thing.

Yeomans believes the Leonid storm is so unpredictable because the clouds of dust around the comet are irregular, perhaps tossed off by outbursts on the comet. If we are lucky and hit a dense clump, we get a storm; if not, we miss out completely. Furthermore, observers have to be in the right place at the right time. The clumps of dust are small and Earth will race through one in just an hour or two. If during that hour you are in daylight, then you are out of luck. This is what happened to Europe and the eastern United States in 1966. If the peak of the storm comes before midnight at your site, Leo will not have risen yet and again you will miss out on most of the fun. And here's the kicker: no one can predict where the best location will be.

There is also a "small" problem with the comet, because no one knows exactly where Tempel-Tuttle is either. Astronomers last saw it in late 1965 as it was heading back toward the outer solar system. Right now the comet should be on its way back to Earth, heading our way like a boomerang. Yeomans' calculations in-


Comet Tempel-Tuttle & the Leonid Meteor Swarm
Sun
Orbit of Earth
Earth on November 17
Orbit of Comet and Leonids

Meeting Earth nearly head-on, the Leonids follow the orbit of Comet Tempel-Tuttle, which passes about 2 million kilometers inside the orbit of Earth. The meteoroids lie just outside the comet's orbit and the richest meteor displays usually come when Earth flies through the swarm soon after the comet has gone past. Diagram by Mark Watson with data from Donald K. Yeomans, JPL.

dicate that if all goes well Comet Tempel-Tuttle will reach perihelion on February 28, 1998.

So what can we expect? Here is a year-by-year storm forecast:

From 1991 to 1995: Forget it. We are so far ahead of the comet that a great storm is almost impossible. However, Leonid activity should increase during these years and in some, the Leonids may outdo the Perseids and Geminids.

1996 and 1997: We are still ahead of the comet, so conditions are not ideal. But a storm is possible either year, as happened in 1799.

1998 and 1999: These are the best years, for we should now be behind the comet. If we run into a clump of dust, some lucky part of the world will witness a grand spectacle.

2000 and 2001: Storms are still possible, but they are less likely, since we are farther from the comet.

But remember that nothing is certain. The only certainty, in fact, is the Moon, whose light will ruin some of the observing opportunities. Fortunately, the Moon will be out of the way during the most important years. It will pose little trouble after midnight in 1996, 1998, 1999, and 2001, but it will interfere greatly in 1997 and 2000.

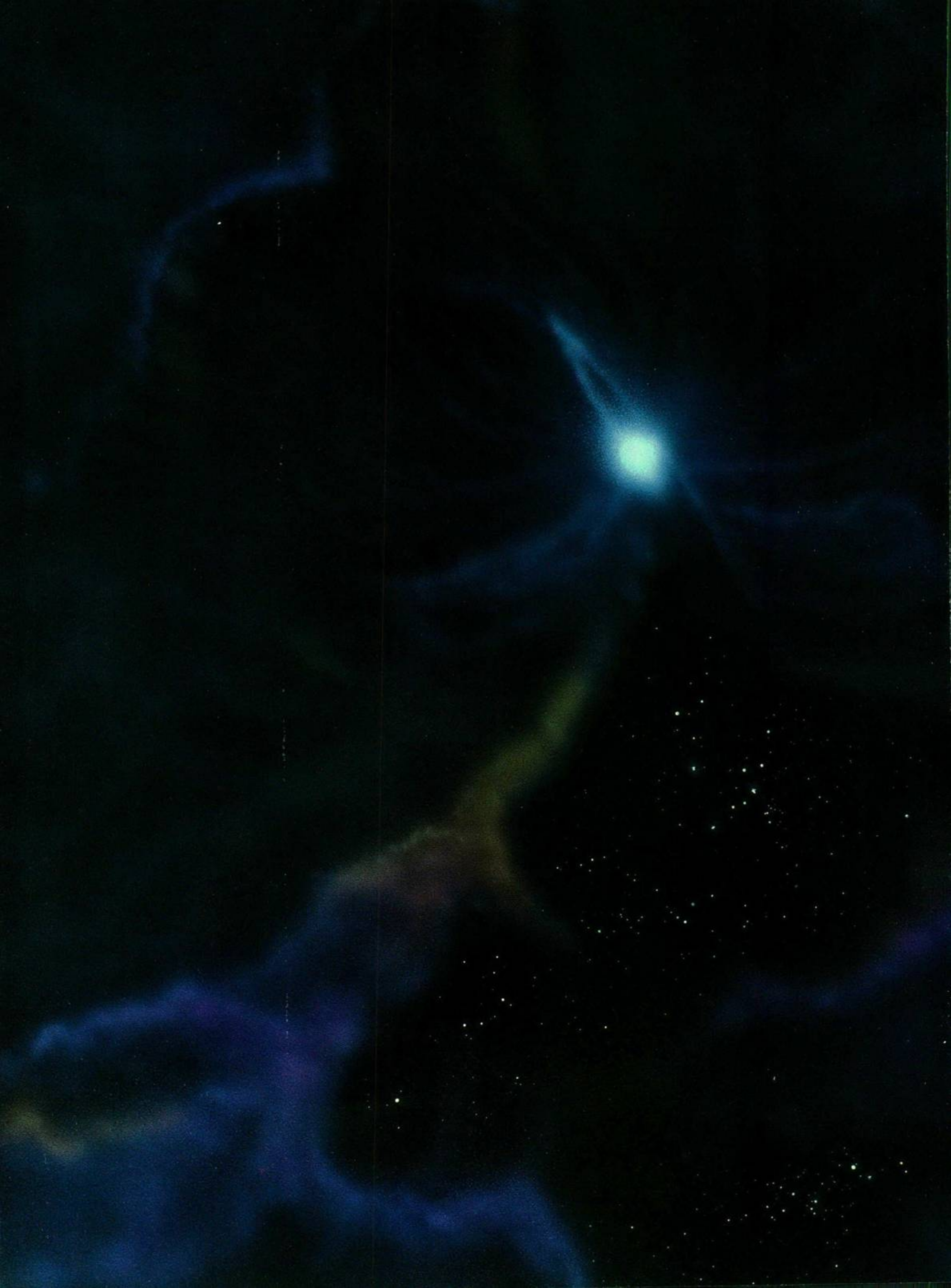
So, during the rest of the 1990s, what should we look for? First, if a storm is coming, meteor watchers should see the Leonids start to intensify. Already there have been some signs.

Second, if the comet really is coming back, astronomers should recover it in 1997 or 1998. The comet's return is another good signal that a major storm may be on the way.

Finally, prepare for the unexpected. The Leonids may storm ferociously in 1998 and 1999 — or they may fizzle out completely. Anything could happen.

But you'd be crazy not to be outdoors, awaiting the return of the Lion's mighty roar. ☐

Ken Croswell has a doctorate in astronomy from Harvard University and has written for New Scientist, Star Date, *and Time-Life Books. His last article for ASTRONOMY was "Does Alpha Centauri Have Intelligent Life?" in the April issue.*

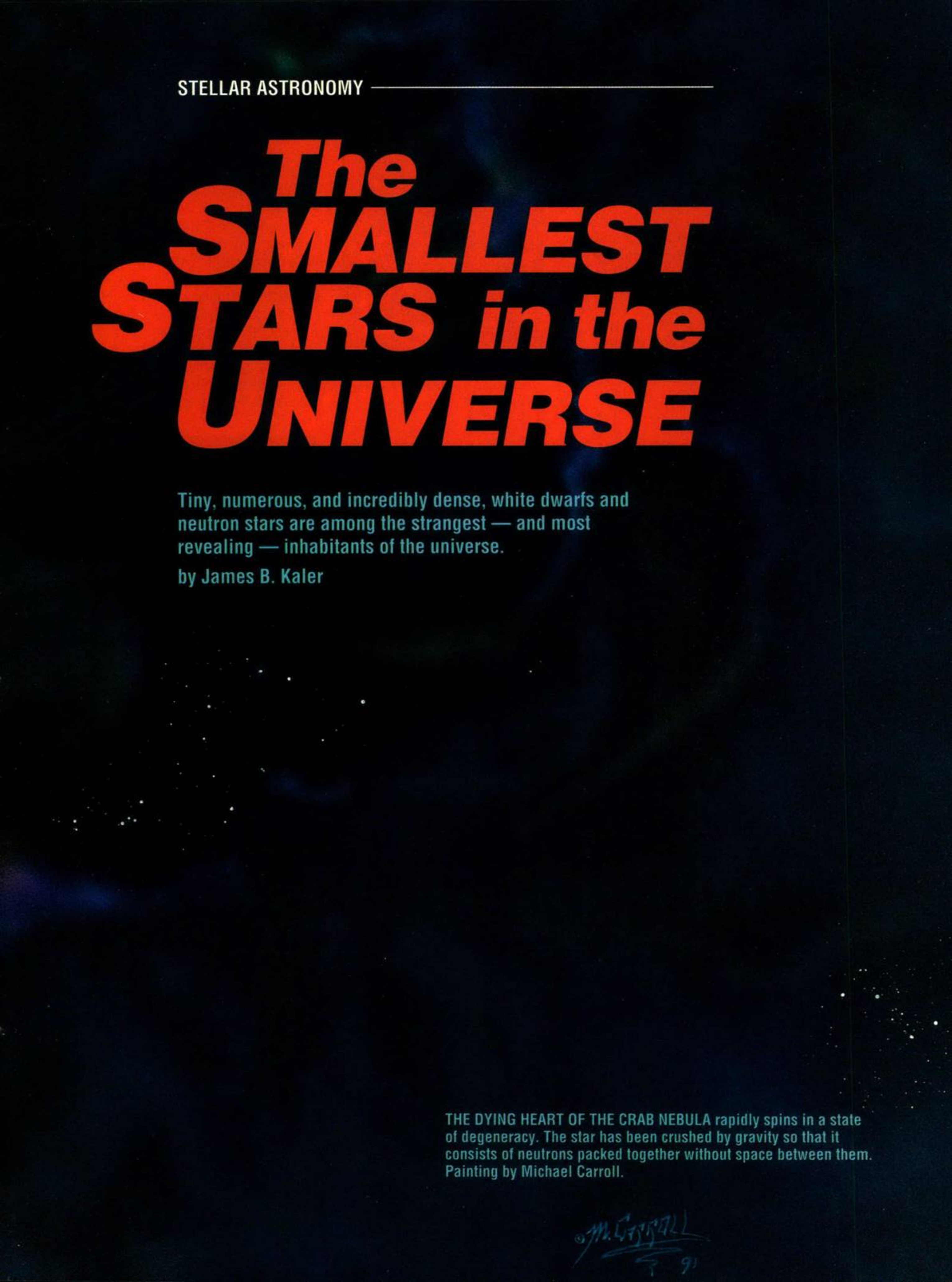


STELLAR ASTRONOMY

The SMALLEST STARS in the UNIVERSE

Tiny, numerous, and incredibly dense, white dwarfs and neutron stars are among the strangest — and most revealing — inhabitants of the universe.

by James B. Kaler



THE DYING HEART OF THE CRAB NEBULA rapidly spins in a state of degeneracy. The star has been crushed by gravity so that it consists of neutrons packed together without space between them. Painting by Michael Carroll.

Thickly scattered throughout the Galaxy is the debris of stellar evolution. This lost material drifts aimlessly in the shadows of once-mighty behemoths, the white dwarfs and neutron stars, to which it once belonged. These white dwarfs and neutron stars are the very cores of suns in which nuclear fires once raged. They are destined to become incredibly dense, slow-cooling celestial ashes that will smolder until the very end of time.

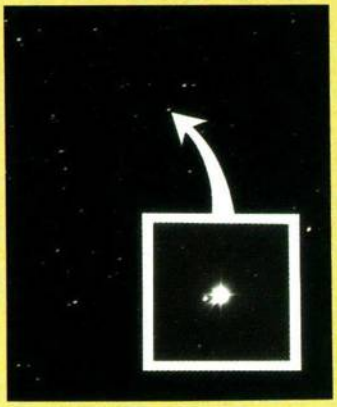
Thus far in our series describing the types of stars in the universe, we've looked at the hottest stars (February 1990 issue), the coolest stars (May 1990), the largest stars (October 1990), the brightest stars (May 1991), and the faintest stars (August 1991). In this final article of the series, we'll turn our attention to the smallest stars.

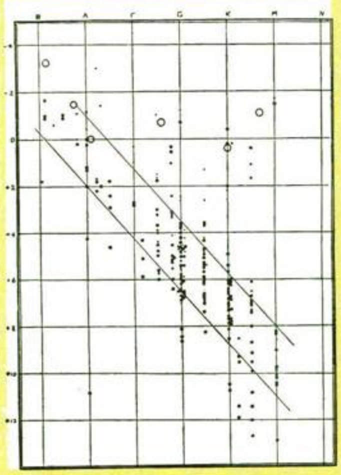
The story of the smallest stars introduces you to the endpoints of stellar evolution. Three types of dense, old, weird objects make up the smallest stars. As once healthy stars exhaust their nuclear fuel and head for the cosmic graveyard, they collapse and become extraordinarily dense. They do this in a succession of sorts, becoming dense white dwarfs or neutron stars. Finally, the ultimate collapse occurs when a dead star becomes a black hole, a region from which nothing can escape. These stellar corpses will be explored in detail below.

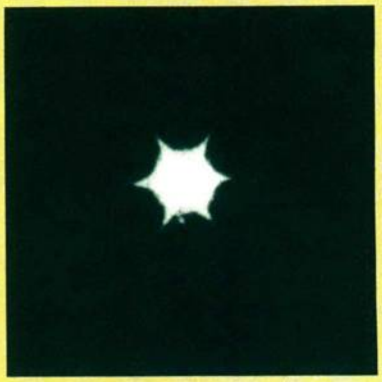
Stretched out in a long thin line on the H-R diagram are the smallest ordinary stars, white dwarfs. Once thought to be rare, they are now known to be common in the Galaxy. In fact, this type of star is the inevitable common endpoint for untold millions of main sequence stars that begin their lives between 0.8 and 8 solar masses. White dwarfs are strange creatures: although comparable to Earth in size, they contain much of the mass of the original star, resulting in an object that is enormously dense. (A tablespoon of starstuff from a normal sun would weigh about the same as a tablespoon of water; a tablespoon of white dwarf material would weigh a million times more!) Widely sprinkled among white dwarfs are the truly rare beasts, neutron stars and pulsars, products of the catastrophic evolution of the most massive stars. These objects almost defy description: massive stellar remnants shrunk to the size of a small town, they contain the densest matter yet observed and madly spin on their axes as many as 1,000 times per second.

As once healthy stars degenerate, exhausting their nuclear fuel and heading for the cosmic graveyard, they collapse and become extraordinarily dense.

THE WHITE DWARFS







The first white dwarf to be discovered, 40 Eridani B, is visible in the inset of this wide-angle photo of the Orion region (left).

Henry Norris Russell's original H-R diagram, which plots absolute magnitude versus spectral class, shows 40 Eridani B as a lone dot in class A near absolute magnitude 11 (bottom left).

White dwarf Sirius B is the tiny dot immediately below brilliant Sirius A (below). The stars have similar masses, so Sirius B's great density is obvious.

All photos and diagrams in this article are courtesy James Kaler.

The Search for Small Stars

The story of white dwarfs goes back to 1844, when German astronomer Friedrich Bessel discovered that neither Sirius nor Procyon moved across the sky in a straight-line path. Bessel hypothesized that these two great stars were being shifted about by "dark stars." The first of these dark stars — actually faint white dwarfs — was actually seen just 18 years later by Alvan Clark as he tested the 18-inch refractor at Dearborn Observatory near Chicago. Sirius B, as it is now called, is an 8th-magnitude star. Were it placed alone in the sky, this nearby white dwarf would be easily visible in binoculars, but its proximity to the glaring, brilliant Sirius makes it extremely difficult to see. Procyon B, three magnitudes fainter than Sirius B, was harder to spot. It was finally seen in 1895 by astronomers at Lick Observatory.

At the turn of the century, all that astronomers knew about these stars was they were dim yet massive. Early orbital calculations showed Sirius B had about one-half the mass of its luminous companion, which itself weighs in at over two solar masses. How could such a dim (and presumably tiny) star be as massive as the Sun? The first hint came when Henry Norris Russell recognized that giant stars were different than main sequence stars in the H-R diagram. For example, Russell investigated a lonely A-type star ten magnitudes fainter than the main sequence stars, a companion to 4th-magnitude 40 Eridani. Russell found that this companion was very faint but, based on orbital motions, had a mass nearly half that of the Sun.

What was happening with this star? Its white color indicated high temperature, so in order for the luminosity to be so low, the star had to be very small and dense. 40 Eridani B, the dim white star, became the first confirmed white dwarf, and two years later Walter S. Adams found that Sirius B is a white dwarf and only about twice as large as Earth, with a density 10,000 times greater than lead.

White dwarfs are weird stars. Crushing densities and pressures are everyday occurrences. Astronomers see vivid evidence of this in white dwarf spectra.

Spectra as Clues to Density

White dwarfs are really weird stars. Crushing densities and pressures are everyday occurrences in these stars. How do astronomers know this? They see vivid evidence in white dwarf spectra. As with all stars, the gravity of the white dwarf packs the densest material at the center and its least dense in a thin atmosphere. The light observed by astronomers is formed in this less-dense atmosphere.

Consider that atoms are mostly empty space. A hydrogen atom with its single electron is about 10^{-8} centimeters across, but the nucleus — the proton — is 100,000 times smaller, which means that only a single part in 10^{-15} of the atomic volume is actually filled. But when atoms get compressed and the amount of space between them decreases, a spectral alarm bell rings: The star's spectrum shows lines that appear to be broadened. Consequently, old, high-density stars have hydrogen lines much broader than main sequence stars. And white dwarfs carry this broadening to an extreme.

English astrophysicist Arthur S. Eddington realized during the 1920s that in a white dwarf the gas had to be fully ionized (the electrons stripped from their nuclei), so that the atoms could be compacted. But the stars still presented a conundrum. As they cooled, the atoms ought to recombine, and the stars should swell. But the stars didn't swell because of their intense gravity. What was going on? The solution came from Robert H. Fowler of Cambridge University by an application of quantum mechanics.

Fowler found that in a white dwarf the electrons are called degenerate. They are packed as tightly together as possible in their phase spaces, like molecules that make up a crystal, and the star can contract no further. The pressure of the degenerate electrons supports the star and keeps it from collapsing. As it cools, the electrons cannot slow down, and except near the star's surface, recombination of electrons and protons cannot take place. The star maintains a constant internal pressure that depends on its mass, and as time goes on cools.

A larger mass white dwarf will be squeezed into a smaller space by its gravity, so that at a given temperature, higher mass white dwarfs will have smaller surface areas and will be less luminous — just the opposite of the behavior of normal stars.

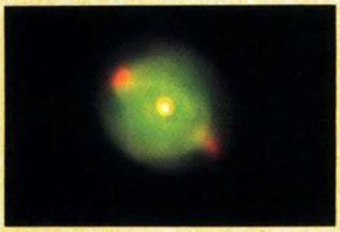
Under conditions of ordinary degeneracy there is no limit to the mass of a white dwarf. But as the star's mass grows, and the densities become higher, conditions are no longer ordinary. The velocities of the highest-speed electrons begin to approach that of light, and now the theory of relativity must be taken into account. Using these principles, S. Chandrasekhar — a student of Eddington's — showed in 1930 that there was a limit to the mass of a white dwarf that could be supported by electron degeneracy. Beyond that mark, the star must collapse, the result

THE CORES OF PLANETARY NEBULAE

The star that created the planetary nebula NGC 6826 in Cygnus is the old core of a once-great giant star (below left). This star is well on its way to becoming a white dwarf.

The aged planetary nebula Abell 6 (bottom left) contains within its center a faint white dwarf that has cooled to below 80,000 K.

The Vela Supernova Remnant (below right) contains a pulsar that emits a powerful beam of energy. The star is so compressed by gravity that it contains no space between atomic nuclei.

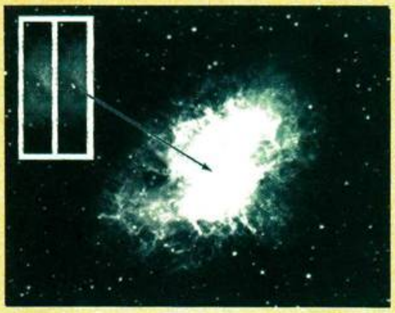


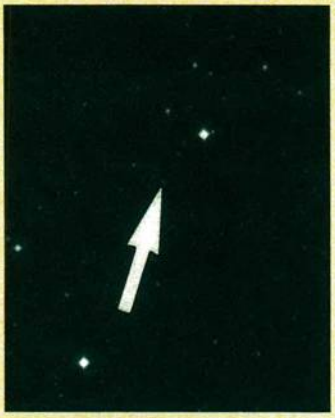
PULSARS, MAGNETISM, AND BLACK HOLES

The Crab Nebula in Taurus contains a rapidly spinning pulsar that flashes 30 times per second (below). The young neutron star responsible is only 10 kilometers across. The inset shows the pulsar between pulses and in mid-pulse.

The magnetic white dwarf PG 1533-057 is a 15th-magnitude star in Libra (right). The object's spectrum reveals a magnetic field 30 million times greater than the Sun's.

What is more degenerate than either a white dwarf or a neutron star? A black hole — and that's what astronomers believe exists in the Cygnus X-1 system (bottom right).





being a neutron star or black hole. Chandrasekhar's discovery was not accepted when he finally presented it in 1935. Eddington simply rejected the concept of relativistic degeneracy out-of-hand, and his influence was so great that nearly two decades would pass before the idea gained general currency.

Creation and Evolution

The life and death cycle of the stars creates these unusual beasts. A star spends its life trying to contract under gravity. Working against this are a variety of conditions, first on the main sequence when nuclear fusion provides energy and outward pressure, keeping the star stable for billions of years. When the fuel runs out the core contracts and heats, igniting the hydrogen in a shell. The result is that the star becomes brighter and larger as it develops into a red giant. Eventually the inert helium in the core becomes hot enough to burn into carbon and oxygen. With the new energy source, the core contraction stops and the star's radius stabilizes. Then, when the helium disappears, contraction again starts, helium burns in a shell around the dead core, and hydrogen in a larger shell around that. The star becomes huge, perhaps as big as the orbit of Mars. The helium shell can turn on and off violently. The outer atmosphere can pulsate, turning the star into a variable.

Dust develops in the wind and the star buries itself in a cocoon as the wind strips away the star's envelope, nearly exposing the core, which is still surrounded by a hot glowing shell and a lightweight atmosphere. The star is now the white-dwarf-to-be. The core then heats as a fast self-generated wind removes the remaining atmosphere from above and nuclear burning eats at it from below. The wind compresses the inner edge of the expanding old envelope, and when the temperature of the atmosphere reaches 25,000 K it produces enough ultraviolet radiation to ionize and illuminate this dense region, which by now has grown to a few thousandths of a light-year across. And suddenly we see a colorful bubble surrounding the old blue-hot core — a planetary nebula forms. As the thin stellar atmosphere disappears, the planetary's nucleus reaches a maximum temperature and then begins to cool and contract. As the nebula dissipates into space, the white dwarf emerges, assumes a size that depends on its mass, and finally gets smaller to cool for eternity.

Imagine a star weighing 1.4 solar masses, measuring 10 kilometers across, spinning nearly once per second. The rotation of the magnetic field powers the beam of radio energy that reaches to Earth.

Stars come in all weights, from 0.08 solar mass to over 100 solar masses. The size of the life-sustaining core and mass of the white dwarf critically depend on the star's initial mass. The lower the initial mass, the longer the star's life. Below about 0.8 solar mass the lifetimes of stars are so long that none have yet been able to evolve off the main sequence. A 0.8 solar mass star ends its life as a white dwarf a bit over half the mass of the Sun, which itself should eventually lose some 45 percent of its mass. Stars with more than 8 solar masses do not become white dwarfs but instead eventually collapse into neutron stars.

The Planetary Nebulae

Studying one known group of white dwarf progenitors, the nuclei of planetary nebulae, helps to show what's going on with these unusual stars. Determining the chemical compositions of white dwarfs is still in a relatively crude state, but we can already see some peculiarities. After all, there is little real difference between the nucleus of a cooling planetary nebula and a white dwarf except time and temperature. Some of the stars are clearly helium deficient, showing what appears to be the settling of helium. Others — a class of bright nuclei on the heating portions of their evolutionary tracks — display Wolf-Rayet characteristics and no trace of hydrogen at all. Their spectra are similar in appearance to massive Wolf-Rayet stars, hot stars with powerful winds revealed by their emission lines. Are they hot degenerate stars in the making?

As strange as these stars are, an even more remarkable event happens as they begin to cool. The gas is so dense that as the white dwarf approaches the bottom end of the evolutionary track it actually begins to crystallize, turning into a solid. The rates of cooling are so long, however, that in the history of the Galaxy, no star has yet had time to do this. If astronomers can find the most degenerate stars we can examine the end-products of the earliest generations of stars. And if we knew the cooling rates of these stars we could measure the age of the Galaxy. These dim reddish stars, near 3000 K and glowing dimly at absolute magnitude 20, are very difficult to locate and study. But we see clearly that these near-dead frozen stars have a significance all out of proportion to their meek presence in our sky.

. . .And Then Came the Neutron Stars

Neutron stars grandly expand upon degenerate behavior. The neutron star is the next contraction state beyond the white dwarf. If the core of an evolving star is — or can grow — larger than 1.4 solar masses, it can no longer support itself by its degenerate electrons and must collapse, the squeeze stopping only when the nuclei of the atoms become degenerate, which occurs at an astounding density of some 10^{12} grams per cubic centimeter — the density of nuclear matter itself. That is, all the space between the atomic nuclei is gone. At these densities, protons and electrons essentially merge and what is left is a small ball of neutrons no more than 10 kilometers or so across. At this density Earth could fit into a cube 100 meters on a side!

A tablespoon of starstuff from a normal sun would weigh about the same as a tablespoon of water. A tablespoon of white dwarf material would weigh a million times more!

Neutron stars were originally proposed as the theoretical remnants of supernovae explosions in the 1930s by astronomers Walter Baade and Fritz Zwicky. Even the odd star at the center of the Crab Nebula was long ago thought to be one. But it took the power of radio astronomy and the discovery of pulsars in 1967 to lift the fog about neutron stars. Pulsars are spinning neutron stars that have powerful magnetic fields. These fields have been squeezed down with the star until they have reached 10^{12} times that of Earth or the Sun. For reasons that no one currently understands, the magnetic field axes are not aligned along the stars' axes of rotation. Radiation showers from the star along the rotating magnetic poles, much like an enormous celestial lighthouse. If Earth is in the pulsar's line of sight, the beam sweeps past us and we get a "pulse" of radiation, hence the term "pulsar."

The regularity of the pulsar signals is amazing. The first one discovered — by Jocelyn Bell of Cambridge University — had a period of 1.3372795 seconds. Imagine a star weighing in at over 1.4 solar masses, measuring just 10 kilometers across, and spinning nearly once per second. The rapid spinning and the resulting rotation of the magnetic field powers the great beam of radio energy that reaches across thousands of light-years to whip past Earth.

Hundreds of pulsars with a variety of periods are known. Some of the fastest are associated with supernova remnants like the Crab Nebula, demonstrating that pulsars are produced in stellar explosions. The Crab pulsar rotates an amazing 30 times per second. (The faster such a pulsar spins, the greater the energy it releases, allowing us to see shorter and shorter wavelength radiation — the Crab pulsar emits x rays.) As regular as it is, over a long period of time a pulsar slows down. A pulsar begins its life whirling quickly within a new supernova. We see the gaseous remnant for a while, and then as time proceeds, the remnant dissipates and the star slows and stops producing visible light, leaving a bare radio-emitting neutron star.

Just what exactly is a pulsar? It is the iron heart of a fully evolved massive star. Successive stages of nuclear fusion in stars allow hydrogen to burn all the way to iron. But iron cannot fuse like other elements. Once an iron core develops, it suddenly collapses and releases a vast amount of energy — more than an entire galaxy — blowing apart the star's outer layers. We witness a distant brilliant point of light, a supernova. The star's core itself continues to collapse until it is stopped by neutron degeneracy. As the star contracts, its spin rate increases, just as a skater's does when the arms are pulled toward the body. By the time the star is a few kilometers in diameter, the rotation rate may be as fast as hundreds of times per second.

White dwarf — neutron star — then what? Electron degeneracy has a limit and so does neutron degeneracy. If the mass of the dense star exceeds about three times that of the Sun, even the neutrons — nuclear matter itself — cannot hold back the force of gravity, and the star collapses. But this time there is no salvation — there is nothing left to stop the contraction and the star collapses forever. The material in the star becomes so dense that light, radio, x rays, and all other forms of energy cannot escape. The object disappears from the view of the universe, becoming a black hole. The gravity is still there, but from an optical observer's viewpoint, the star is gone from space. Astronomers can detect the presence of black holes only by their effect on another star close by, either by Doppler shifts it induces in an orbiting neighbor or by the accretion of matter from the companion star. We have reached the limit of comprehension of the astrophysical zoo.

Professor Bessel began a remarkable field of study some 150 years ago when he noted something very strange about Sirius. It opened the whole field of stellar death, from the numerous white dwarfs to the rare pulsars to the enigmatic black holes. How he surely would have enjoyed the results of his labors. □

James B. Kaler is a professor of astronomy at the University of Illinois. His last article in ASTRONOMY was "The Faintest Stars" in August 1991.

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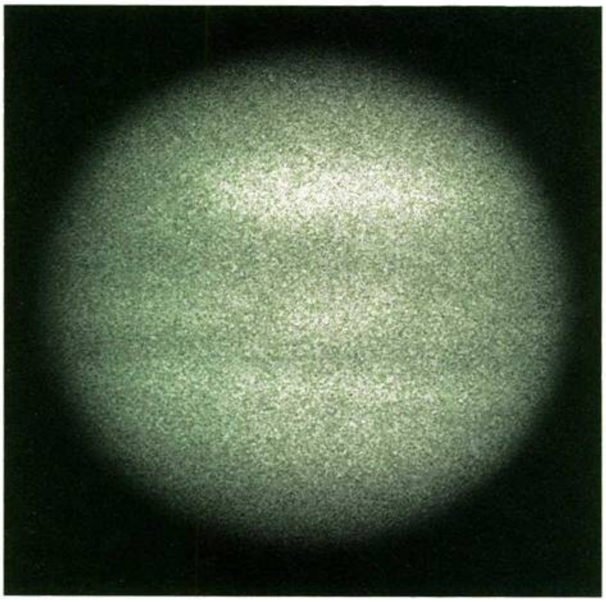
Could be Jupiter.



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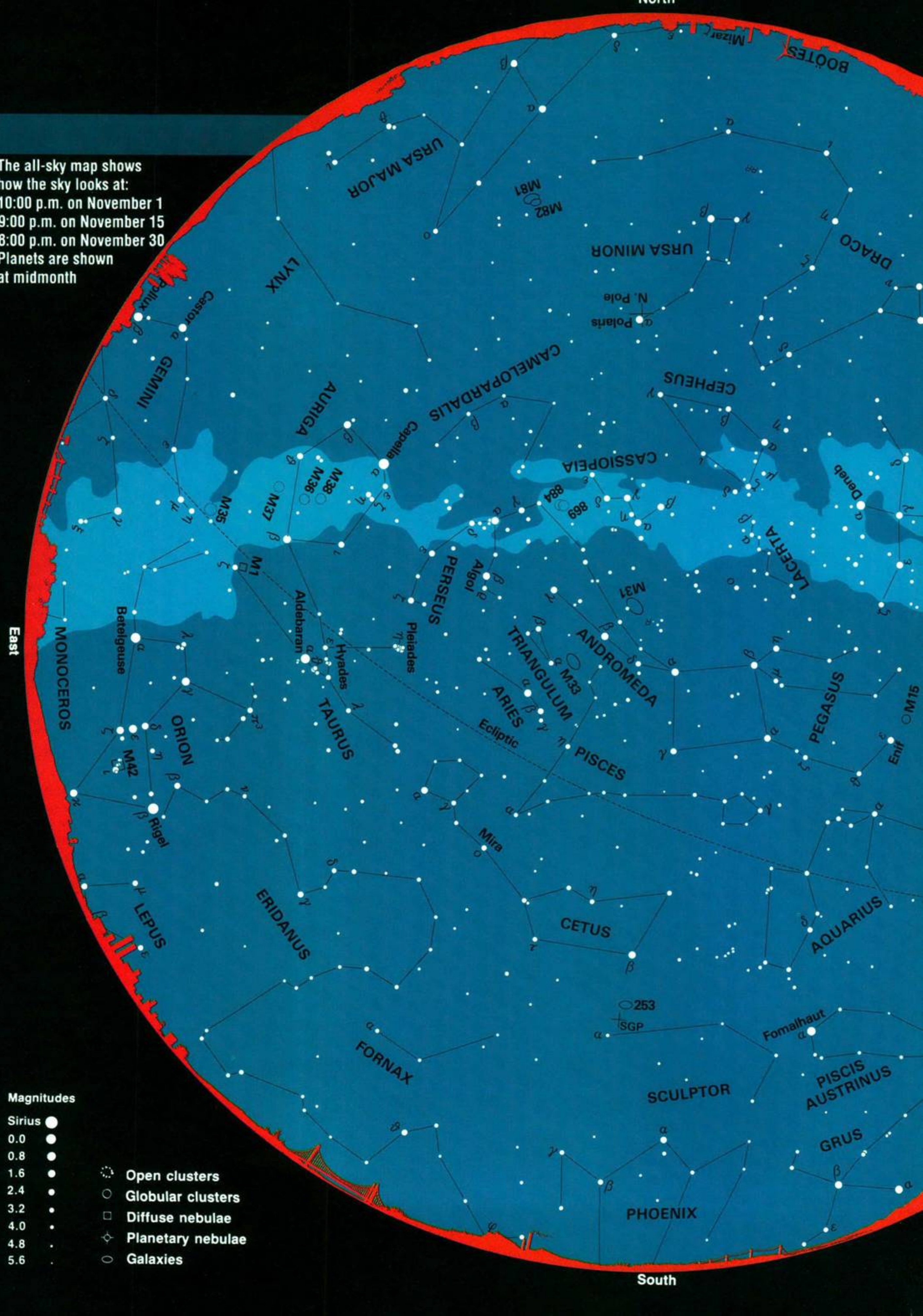
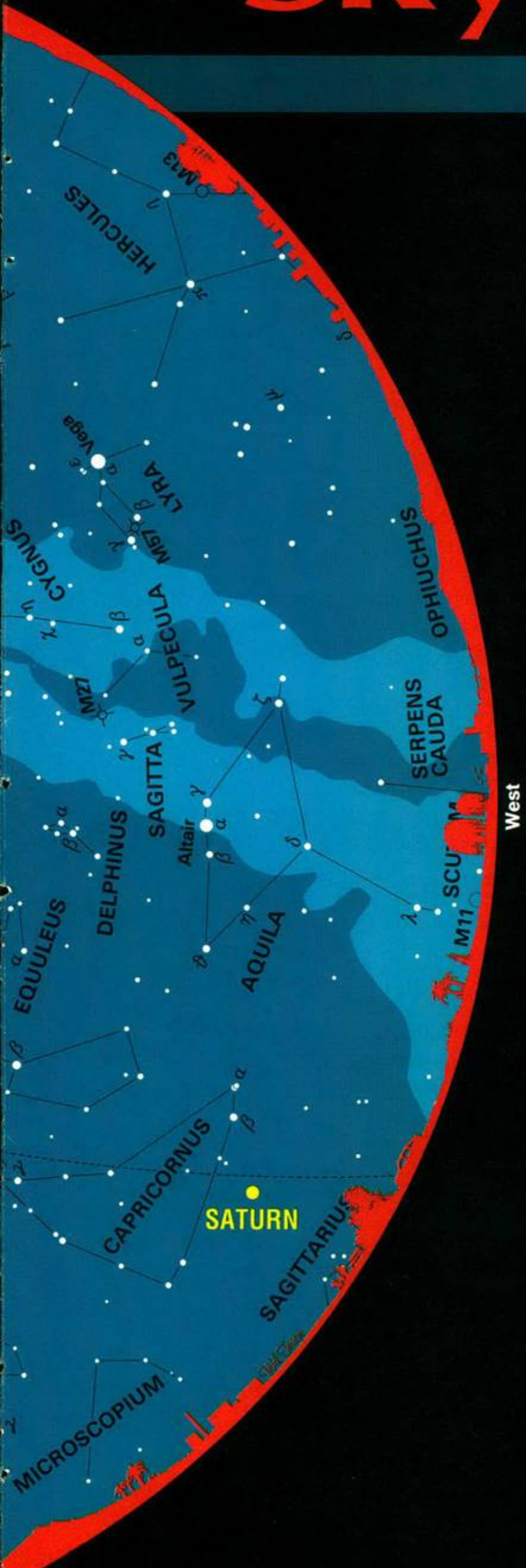
The all-sky map shows how the sky looks at:
10:00 p.m. on November 1
9:00 p.m. on November 15
8:00 p.m. on November 30
Planets are shown at midmonth



Sky Almanac

November 1991



VENUS BRIGHT IN THE MORNING

Venus appears high in the predawn sky this month because it reaches its greatest elongation west of the Sun on November 2. The brightest planet rises nearly four hours before the Sun and is 25° above the east-southeast horizon when morning twilight begins.

A PAIR OF METEOR SHOWERS

Both the Taurid and Leonid meteor showers peak this month, with each promising to fill the sky with a dozen or so meteors per hour. The Taurids have a broad peak lasting the first two weeks of November, when the crescent Moon will create few viewing problems. The Leonids peak on November 17/18, when the waxing gibbous Moon hampers viewing except in the two hours before morning twilight begins.

MERCURY AT GREATEST ELONGATION

Like Venus, Mercury reaches greatest elongation this month. Unlike Venus, however, Mercury lies east of the Sun and appears low in the southwest after the Sun sets. Look for the innermost planet about 30 minutes after sunset on November 18, when it is at greatest elongation, or on the 10th when it passes just 2° from Antares.

NEPTUNE NEAR A BRIGHT STAR

Although Neptune is usually a difficult object to find, the task is made easier this month by its proximity to the 4th-magnitude star Omicron Sagittarii. The most-distant planet passes just 7' south of the star on November 22.

Calendar of Events

2 Venus is at greatest western elongation (47°)
4 Pallas is in conjunction with the Sun
6 New Moon is at 6:11 a.m. EST
7 The Moon passes 0.7° south of Mercury, midnight EST
8 Mars is in conjunction with the Sun
11 Mercury passes 2° north of Antares, 2 a.m. EST
12 The Moon is at apogee (251,537 miles from Earth), 2:32 a.m. EST
The Moon passes 2° north of Saturn, 5 p.m. EST
Pluto is in conjunction with the Sun
14 First Quarter Moon is at 9:02 a.m. EST
17 Leonid meteor shower peaks
18 Mercury is at greatest eastern elongation (22°)
21 Full Moon is at 5:56 p.m. EST
23 The Moon is at perigee (225,521 miles from Earth), 9:25 p.m. EST
28 Last Quarter Moon is at 10:21 a.m. EST
29 Venus passes 4° north of Spica, 4 a.m. EST

VENUS AT ITS PEAK

Venus, the brightest of the planets, is at the height of its current morning apparition in November. It appears at its maximum distance west of the Sun, or greatest western elongation, on November 2. The planet then lies 47° from the Sun and shines brilliantly at magnitude –4.4. It rises nearly four hours before the Sun and can be seen against a dark sky background for over two hours. The waning crescent Moon pays tribute to Venus at this elongation by appearing near the planet on the morning of the 2nd.

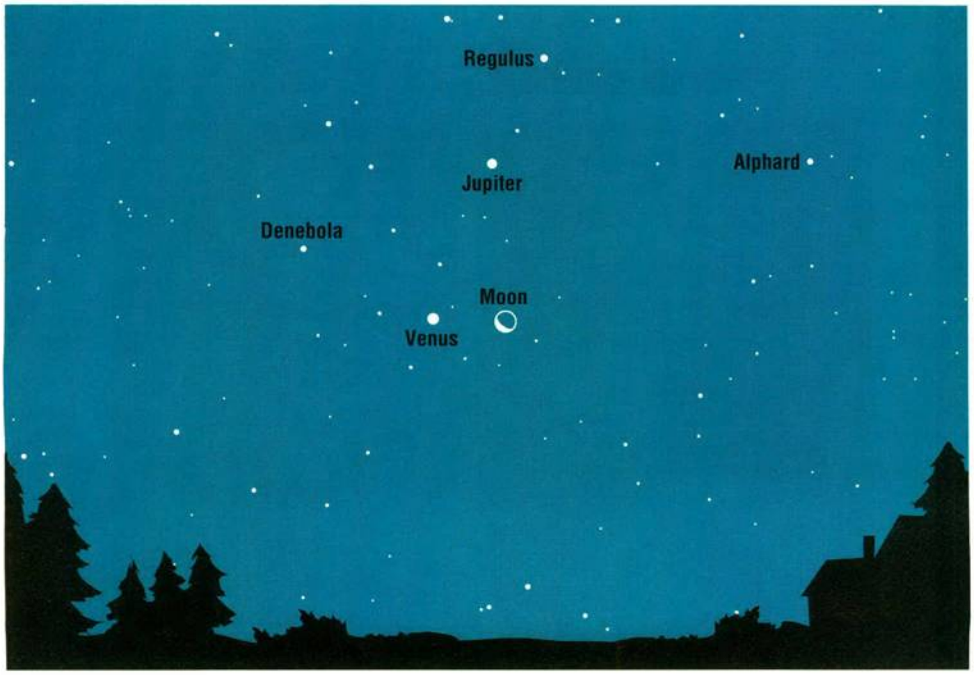
Venus is now slightly higher and brighter than it was in June, when it was at greatest elongation east of the Sun. At that time Venus shone brightly in the evening sky, in the company of Jupiter, Mars and, fleetingly, the young Moon. Now Venus appears more solitary and splendid. It will shine brightly and be extremely obvious to early risers in the chill predawn hours all this winter.

Venus begins the month against the background stars of Leo, but quickly crosses into neighboring Virgo. The Maiden is a large constellation made up primarily of moderately bright stars, but one stands out from the others. This is 1st-magnitude Spica, which represents an ear of wheat that the Maiden holds in her hand. Start looking for Spica around November 4, when it lies 6° to the lower left of the thin crescent Moon. Venus passes 4° north of Spica on November 29 and appears close to the bright star during the last few days of the month.

Although most people associate stargazing with the nighttime hours, you can see Venus in the daytime when the planet is as far from the Sun as it is now. Just go outdoors before dawn and locate the glittering world in the east-southeastern sky. Then keep an eye on it until after the Sun rises. If sky conditions are good and you don't get distracted by other wonders of the new day, you'll be rewarded with the sight of Venus as a pale but dauntless beacon in a fresh blue sky.

A SHOWER OF NOVEMBER METEORS

Meteor-watching is one of the easiest and most exciting activities in astronomy. The last superb meteor shower was this summer's Perseid shower; neither of the two showers this month are likely to equal that one. Still, for those of you starved for the sight of "shooting stars" sizzling across the heavens, you'll want to take advantage of these opportunities.

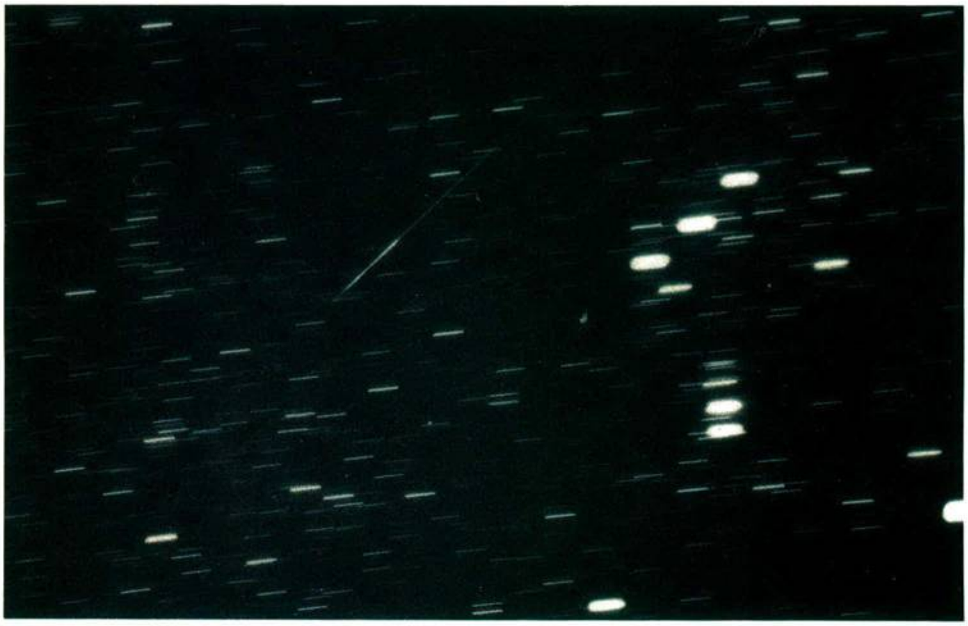


VENUS LIES HIGH in the east-southeast before dawn on November 2, when the bright planet is at greatest elongation for this apparition. By coincidence, the waning crescent Moon lies near Venus that same morning.

The first shower this month is the Taurid meteor shower, which peaks during the first two weeks of November. This shower has a broad peak because it consists of two components that peak at slightly different times. Taurid meteors tend to be bright, with some fireballs, and travel at about 20 miles per second, which is relatively slow by meteor standards. Fortunately, the Moon is gone from the prime after-midnight observing hours this year, when you can expect to see an average of about a dozen meteors per hour.

The other, more famous November meteor shower is the

Leonid shower, which peaks on the evening of November 17. Although the Leonids have produced some fantastic meteor storms in the past (see "Will the Lion Roar Again?" on page 44), in most years they produce about the same number of meteors as the Taurids. Still, these are not just any meteors — Leonids are often bright and they race through our atmosphere at 45 miles per second, the fastest of any shower meteors.



SCAN FOR SHOOTING STARS during the peak of the Taurid meteor shower in early November. Janos Papp captured this –2nd-magnitude Taurid fireball passing near Orion during the 1981

Unfortunately, the conditions for this year's Leonid meteor shower are almost a repeat of what we had for last month's Orionid meteor shower. In other words, the Moon is waxing toward Full when the shower peaks. The best time to observe this shower is in the two- to three-hour window between moonset and the beginning of morning twilight on the mornings of November 17 and 18.

To observe either of this month's showers, get out beneath a dark country sky where you'll be able to see as many meteors as possible. Dress warmly and take along a lawn chair or blanket to lie on so you'll remain comfortable. Then gaze up at the sky and marvel at the celestial light show.

NOVEMBER'S PLANETS

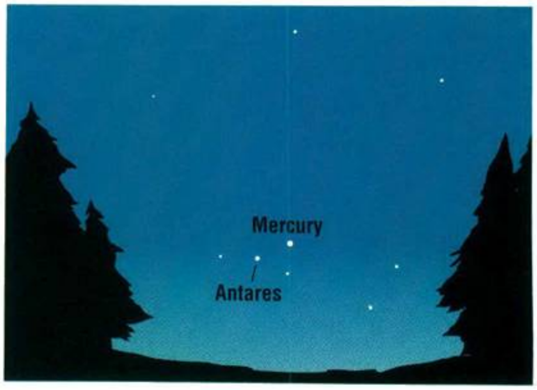
Saturn lies low in the south when night begins. The planet and its background constellation Capricornus, which resembles a broad arrowhead, appear farther to the west each evening throughout the month. Saturn shines at magnitude 0.6, making it by far the brightest "star" among the rather dim real stars of Capricornus.

Jupiter starts this month with a bang. On November 1, it lies high in the predawn sky near the waning crescent Moon — a lovely sight! Jupiter rises earlier each day throughout the month and thus appears progressively higher in the predawn sky. It is also growing slowly brighter as the distance between it and Earth decreases. This month, it shines at magnitude –1.9 and lies not far from the bright star Regulus.

Not long after Jupiter rises, Venus comes blazing over the eastern horizon. In early November, Venus lies about 12° below Jupiter while Regulus is about 10° above Jupiter. The three objects form a magnificent line in the east before dawn, with the faintest (Regulus) on top and the brightest (Venus) on the bottom. At magnitude –4.4, Venus shines brighter than any other star or planet. Its greatest elongation, when it is farthest from the Sun for this morning apparition, comes on November 2.

Mercury also reaches greatest elongation this month. On November 18/19, the innermost planet lies 22° east of the Sun, placing it in the evening sky. Because the ecliptic — the path of the planets across the heavens — makes a narrow angle with the western horizon in the evening at this time of year, Mercury remains low in the sky throughout this apparition. In fact, even locating it is a good test for observers. Use binoculars to find it around the time of greatest elongation, when it shines at magnitude –0.3 and lies 5° above the southwestern horizon half an hour after sunset. Also look for it on November 10, when it passes 2° from the bright star Antares.

ELUSIVE MERCURY has an unfavorable evening apparition in November, but it is worth seeking with binoculars on the evening of the 10th when it passes only 2° from the bright star Antares in the southwestern sky.



Mars remains lost in the Sun's glare throughout November. It passes behind the Sun as seen from Earth on November 8.

THE STARRY SKY

The constellation Andromeda the Princess is as lovely as its namesake. Its primary stars — Alpha, Beta, and Gamma Andromedae — form a graceful arc extending northeast from the Great Square of Pegasus. Look for this constellation ascending in the east on November evenings.

According to ancient Greek mythology, Andromeda was carried to safety by Pegasus, a winged horse ridden by the young hero Perseus. In the sky as in the story, the horse sweeps the princess high into the heavens, then carries her down toward the west again, as the stars make their nightly journeys across the sky.

The head of Andromeda is represented by the star Alpheratz, or Alpha Andromedae, which shines at magnitude 2.1. This star marks the northeast corner of the Great Square of Pegasus. It once had the peculiar distinction of being assigned to two constellations. It was called both Delta Pegasi and Alpha Andromedae. The International Astronomical Union gave the star solely to Andromeda back in the 1930s, in its attempt to regularize the heavens.

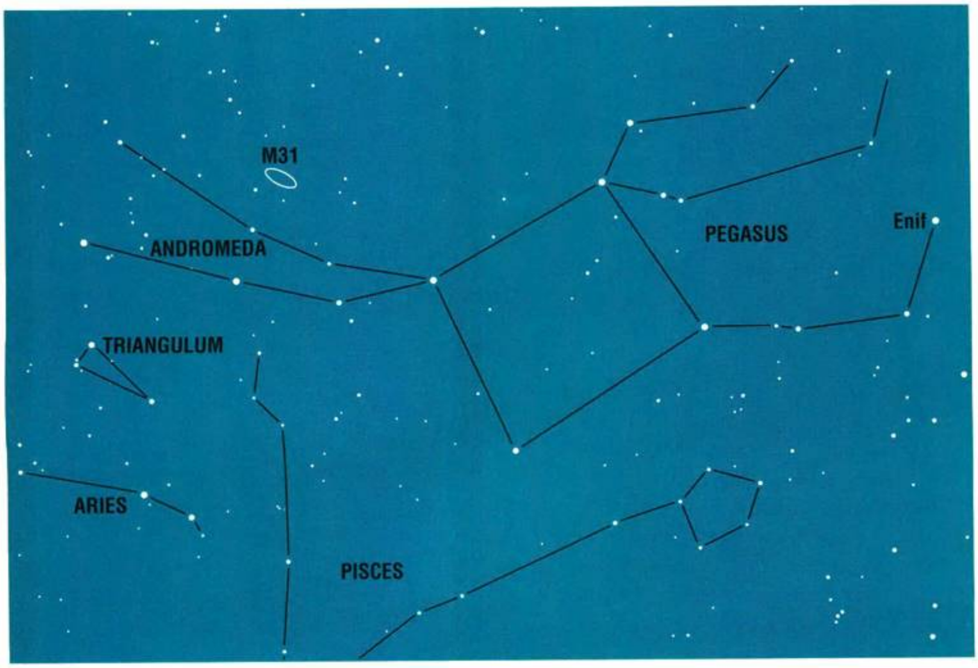
If you see nothing else in your exploration of the night sky, you must see the galaxy in the constellation Andromeda. It is one of the most extraordinary objects available to human sight. This little patch of light — it spans over two Full Moon diameters — contains several hundred billion stars and is located more than 2 million light-years away! It's a marvelous sight through binoculars and small telescopes.

To get a good view of the Andromeda Galaxy, which is also known as M31, go to a country location on a moonless night. The first and last weeks of November work this year, because the Moon is then out of the way. The easiest way to find the galaxy is to first locate Beta Andromedae, which shines at magnitude 2.1. A little line of stars leading northwest from Beta points to the Andromeda Galaxy. (See the map at left.)

I enjoyed reading in the 1911 edition of William Tyler Olcott's famous book *Star Lore of All Ages* that "recent and more reliable calculations of [M31's] distance give it a light journey of about nineteen years." How our view of the cosmos has changed in such a short time! Some argued that this object was a cloud of gas, until the advent of large telescopes around the turn of the century showed that it contained mostly stars. We now know it to be a large spiral galaxy, thought to be similar in appearance to our own Milky Way. Modern distance estimates place it more than 2 million light-years away, making it the most distant object visible to the naked eye. ☐

Deborah Byrd is writer, coproducer, and cohost of the nationally syndicated radio series Earth and Sky.

TWO GRACEFUL STELLAR ARCS form the easily recognized pattern of Andromeda, a bright constellation that lies high in the east on November evenings.

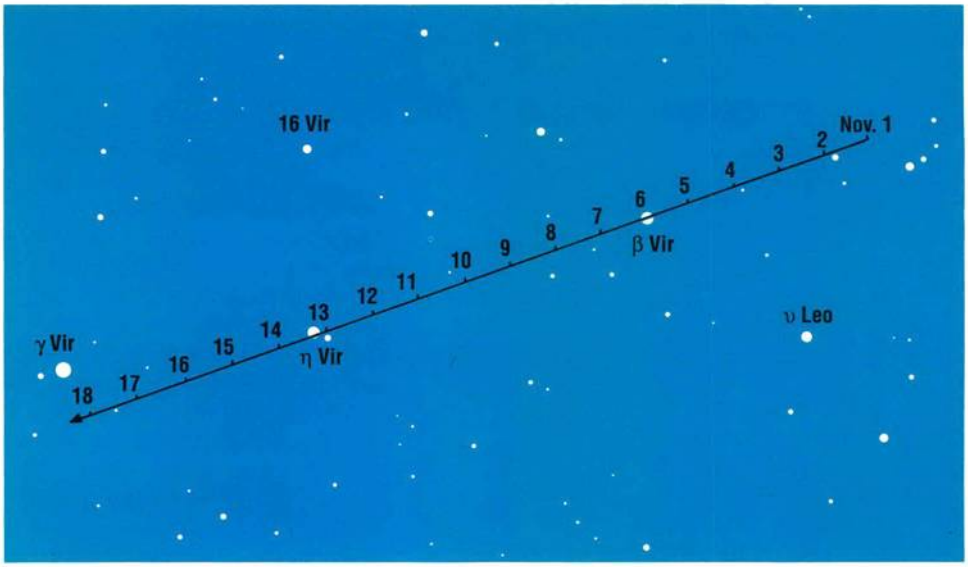


Through the Eyepiece by *Jeff Kanipe*

VENUS SQUEEZES THROUGH VIRGO

Wipe the sleep from your eyes, grab a cup of coffee or English Breakfast tea, and break out your telescope for the predawn hours of the 6th and 13th this month. On each of these mornings Venus passes very near a bright star in Virgo.

On the 6th, Venus passes just 0.1° north of 3.6-magnitude Beta (β) Virginis, which lies near Virgo's border with Leo. And on the 13th, Venus edges a mere 0.02° — 1.3 arcminutes — south of 3.9-magnitude Eta (η) Virginis, which lies about 8° southeast of Beta. In a 3- or 4-inch telescope at 75x to 100x, Venus appears half-lit, but tends toward gibbous as the month progresses.



VENUS TRAVERSES WESTERN VIRGO in the first half of November, passing extremely close to two 4th-magnitude stars. Look for Beta (β) Virginis 6' south of Venus on the morning of November 6, and Eta (η) Virginis just 1.3' north of the planet on the 13th.

I wish I could turn up the "excitement gain" on this event a little by saying that Beta and Eta Virginis were unusual double or multiple stars or variable stars, or that these stars will have some *effect* on Venus, but that wouldn't be true. Basically, Beta is an F-type star about 33 light-years distant; Eta, a hotter A-type star, lies some 100 light-years away. There are no companions and no anomalous variations.

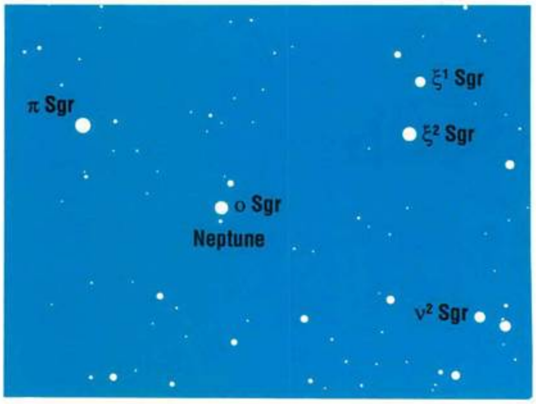
So why bother, you ask? You'll have to answer that one for yourself. Basically, these events are celestial Rorschach tests: you see what you want to see. Some folks will merely observe a planet passing near a star, a mere coincidence of position on the celestial sphere. Others will get something more out of these rare alignments — some indefinable *something* that makes backyard astronomy worthwhile.

NEPTUNE SLIPS BY OMICRON SAGITTARII

Another star-planet conjunction occurs this month, but you'll have to look more carefully to see this one. Neptune will be in the vicinity of Omicron (o) Sagittarii, a 3.8-magnitude double star located 5° northeast of the handle of the Teapot asterism. Since Sagittarius sets an hour or so after twilight ends, you will need to set up around dusk and begin observing in the deepening twilight. And yes, you will need a clear view toward the southwestern horizon. You folks in the endless wheat- and cornfields of the Great Plains are perfectly placed. Weather permitting, if you come, you will see it.

Although it lies in a fairly rich star field, you should have little trouble picking Neptune out of the dusty sprinkling of background stars. It's the 8th-magnitude, sky-blue dot lying 40' southwest of Omicron at the beginning of the month. This angular distance shrinks to just 7' south by the evening of November 22 (see the map at right). You should be able to fit Neptune, Omicron, and its 13.7-magnitude companion, which lies about 35" to the southwest, all within a single field of view, even at moderate magnification. But don't confuse Neptune with the other stars surrounding Omicron, particularly the 7th-magnitude star lying to its north-northwest. Being a planet, Neptune exhibits a disk — albeit one only 2.2" across — that makes it appear slightly "bloated."

YOU CAN FIND NEPTUNE quite easily this month, because it passes only 7' south of the 4th-magnitude star Omicron (o) Sagittarii on the evening of November 22.

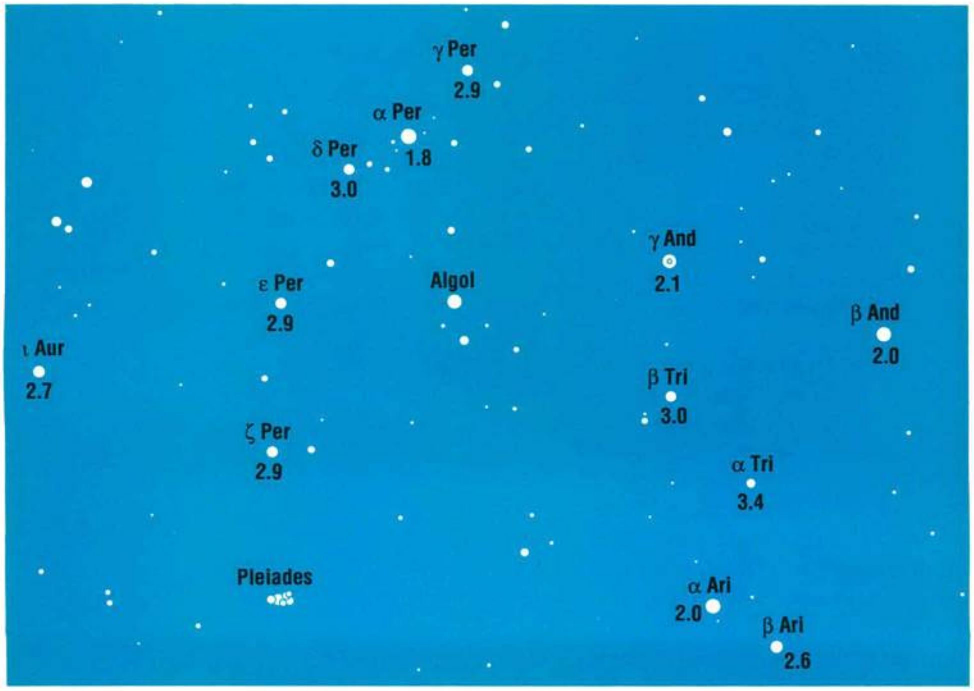


MINIMA OF ALGOL

Date	UT
November 2	19h04m
November 5	15h53m
November 8	**12h42m**
November 11	**9h31m**
November 14	**6h20m**
November 17	**3h09m**
November 19	**23h58m**
November 22	20h47m
November 25	17h36m
November 28	14h25m

Times are given in universal time. Subtract 5 hours to convert to EST, 6 hours for CST, 7 hours for MST, and 8 hours for PST. Minima shown in boldface are visible from at least part of North America.

DEMON-STAR ALGOL fades from magnitude 2.1 to 3.4 every 2.87 days, when its companion star partially eclipses it from our view. You can gauge these brightness changes by comparing Algol with nearby stars of known magnitude (below) around the times of its minimum brightness (above).



GET HOOKED ON JUPITER

The largest planet in the solar system is now a bright beacon shining through the dark trees along the eastern horizon around midnight. Its brightness (magnitude –1.9) and its apparent size (35") will both increase as the planet moves toward opposition next February.

If you're not a planet observer by nature, you may find yourself getting hooked after looking at Jupiter through a telescope a few times. Even a 2-inch scope at 30x readily shows Jupiter's North and South Equatorial Belts (the north belt is still subdued) as well as the planet's most famous feature, the Great Red Spot. The GRS, as veteran planet observers call it, should perhaps be renamed the Great Ghost Spot, since, as of this writing, it is still a washed-out salmon-hued oval embedded in the South Equatorial Belt. Reports of its strengthening so far seem to be greatly exaggerated.

A well-collimated 8-inch reflector or a 4-inch refractor will show you the more subtle atmospheric features seen in and around the equatorial regions of the planet. For example, look for bluish plumes or filaments projecting into the Equatorial Zone from where the North Equatorial Belt (NEB) should be. These features, called festoons, are fairly easy to discern at 150x. A festoon may either cross into the equatorial zone from the NEB or arch outward from the belt's edge and return to another location on the belt (a "loop festoon"). If you watch these features during the course of an evening, you may notice them changing shape slightly as the disk rotates. Festoons are thought to be holes in Jupiter's upper cloud deck, allowing us to peek into deeper layers.

If your seeing is especially steady and clear, you may notice white spots or ovals in and around the equatorial zone. These features are small and difficult to see when the planet's disk is bright, so use high magnification when the seeing allows or try observing the planet near dawn, when the planet's glare is subdued by a brightening sky. White spots and ovals are storms like the Great Red Spot, but on a much smaller scale.

And of course there are Jupiter's beautiful Galilean moons — Io, Europa, Ganymede, and Callisto, in order of greater distance from the planet. Like a miniature solar system, these bodies swing about the giant planet, alternately disappearing and reappearing from view, or crossing in front of Jupiter and appearing silhouetted, like a pencil dot, against its disk. The table opposite lists the best of these phenomena for Western Hemisphere observers during November.

There are so many features visible through a good 8- or 10-inch telescope it would require a lengthy article to describe them all. (See "Jupiter's Best Show in Twelve Years" by Jose Olivarez, November 1987.) This planet never ceases to fascinate me. Perhaps what's most attractive about Jupiter is its potential: you never know what you will see when it comes into view.

THE DEMON RETURNS

Want to try something a little different this month? How about observing a variable star? Of all the astronomical phenomena visible in the humble backyard telescope, a variable star may be the most intriguing as well as the most underrated. True, the majority of variables don't fluctuate dramatically, but there are a few that exhibit noticeable brightness changes over a period of a few days.

One of the most famous and beguiling of variable stars is Algol in Perseus, which is now well up in the eastern sky by 7 p.m. Algol is a cheerful little Arabic word meaning "the ghoul." Located in the western leg of Perseus, Algol is that constellation's second-brightest star and was the first eclipsing binary to be discovered. The brighter component, which is three times the Sun's diameter, is eclipsed by a larger, darker companion (darker compared to the primary star), causing the overall brightness to fluctuate.

Algol's period — from one minimum in brightness to the next — is 2.87 days or 69 hours. During this period, Algol brightens from magnitude 3.4 to 2.1 and then fades back to 3.4 again, although the star remains brighter than magnitude 2.2 about 85 percent of the time. You can easily follow the rapid brightness changes around minimum light by comparing Algol's brightness with that of nearby stars of known magnitude using the chart on the opposite page.

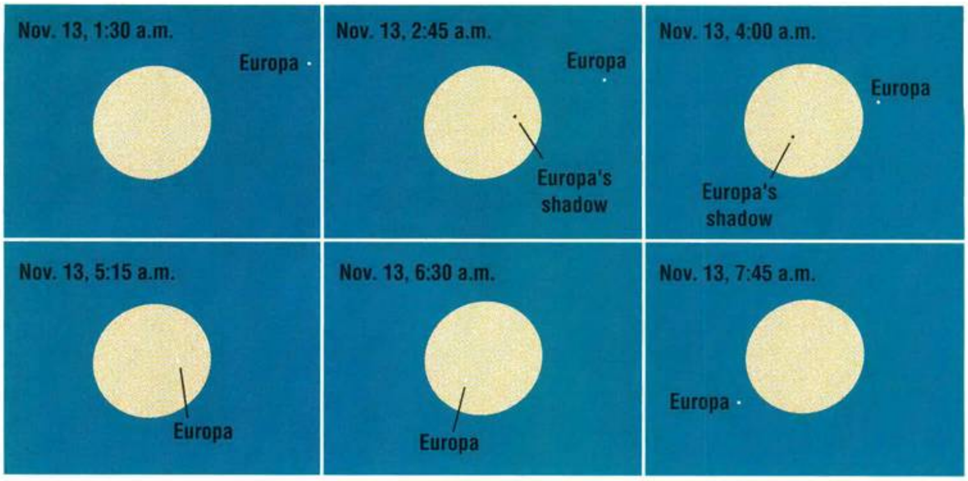
Algol peaks in brightness about twenty-five hours after minimum light, so even though its maxima and minima don't always occur during prime observing time, changes in the star's brightness are usually evident from night to night.

A good period to observe Algol's rise in brightness is from November 16 to 20. It is at minimum around 10 p.m. EST on the 16th and reaches maximum around 11 p.m. EST on the 17th. By early evening on the 19th, Algol has "winked" to minimum brightness. It shines at maximum again around midevening on the 20th.

Variable-star observing is one of those efforts that can swiftly turn into a runaway passion. Some amateur astronomers are compelled to observe more and more difficult variables with their telescopes. Others take to compiling their observations into a "light curve" — a peaks-and-valleys record of a variable's rise and fall in brightness. They then send their light curves to organizations (such as the American Association of Variable Star Observers at 25 Birch Street, Cambridge, MA 02138) whose purpose is to archive such data for scientific use.

As for us recreational observers, all this work makes us tired. We prefer to get our kicks from seeing a star that looks different from the way it looked the previous night, watching features shift across the face of Jupiter, and witnessing the ephemeral asterism of a few well-placed stars and a wandering planet. Viewing these things *does* something for us. Time spent observing the nuances of the night sky may be one of the best emotional investments you can make. □

A former associate editor of ASTRONOMY, Jeff Kanipe is the editor of Star Date *magazine, which is published by McDonald Observatory at the University of Texas at Austin.*



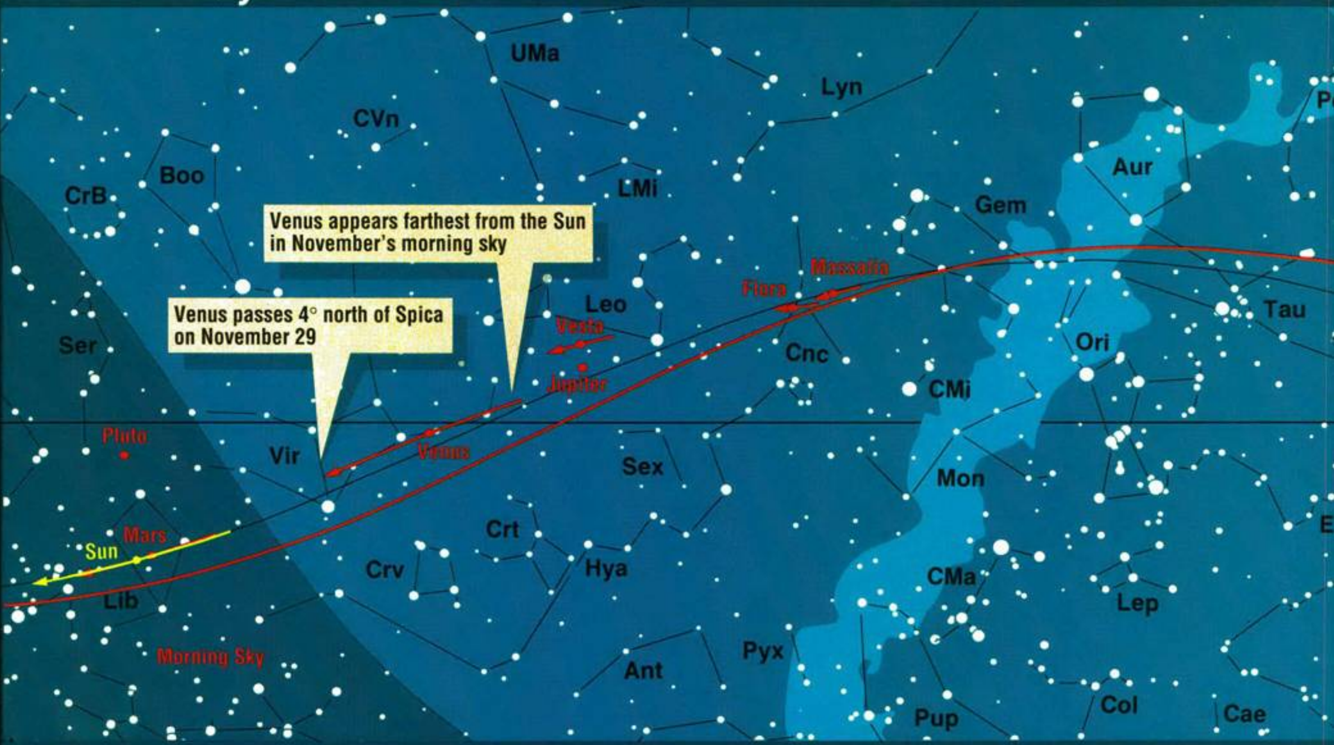
EUROPA AND ITS SHADOW race across the face of Jupiter on the morning of November 13 (above; south is at top and times are eastern standard). Watch this and the other phenomena of the Galilean moons that take place this month.

GALILEAN SATELLITE PHENOMENA

Date	Event	Time
	IO	
Nov. 10	Shadow enters	3:04 a.m.
	Transit begins	4:13 a.m.
	Shadow leaves	5:21 a.m.
	Transit ends	6:29 a.m.
Nov. 25	Eclipse begins	3:58 a.m.
	Occultation ends	7:29 a.m.
Nov. 26	Shadow enters	1:20 a.m.
	Transit begins	2:33 a.m.
	Shadow leaves	3:36 a.m.
	Transit ends	4:48 a.m.
	EUROPA	
Nov. 13	Shadow enters	2:08 a.m.
	Transit begins	4:28 a.m.
	Shadow leaves	4:56 a.m.
	Transit ends	7:14 a.m.
Nov. 29	Eclipse begins	2:23 a.m.
	Occultation ends	7:41 a.m.
	GANYMEDE	
Nov. 3	Shadow enters	12:00 mid.
	Shadow leaves	3:35 a.m.
	Transit begins	4:25 a.m.
	Transit ends	7:57 a.m.
Nov. 28	Eclipse begins	1:54 a.m.
	Eclipse ends	5:30 a.m.
	Occultation begins	6:57 a.m.
	Occultation ends	10:28 a.m.

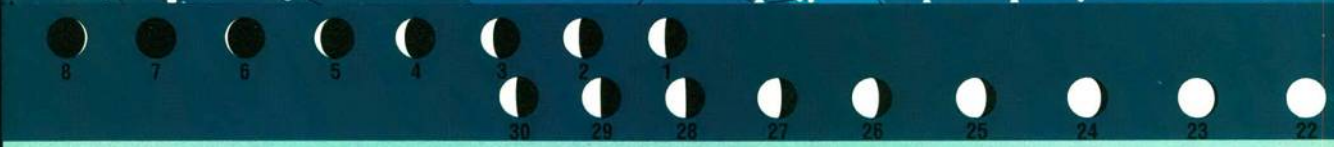
Times are given in eastern standard time. Subtract 1 hour to convert to CST, 2 hours for MST, and 3 hours for PST.

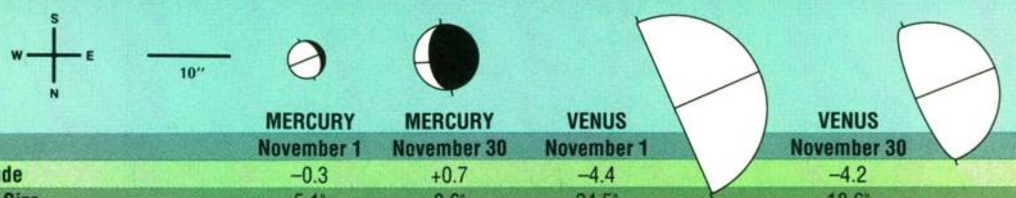
The Solar System November 1991



Venus appears farthest from the Sun in November's morning sky

Venus passes 4° north of Spica on November 29

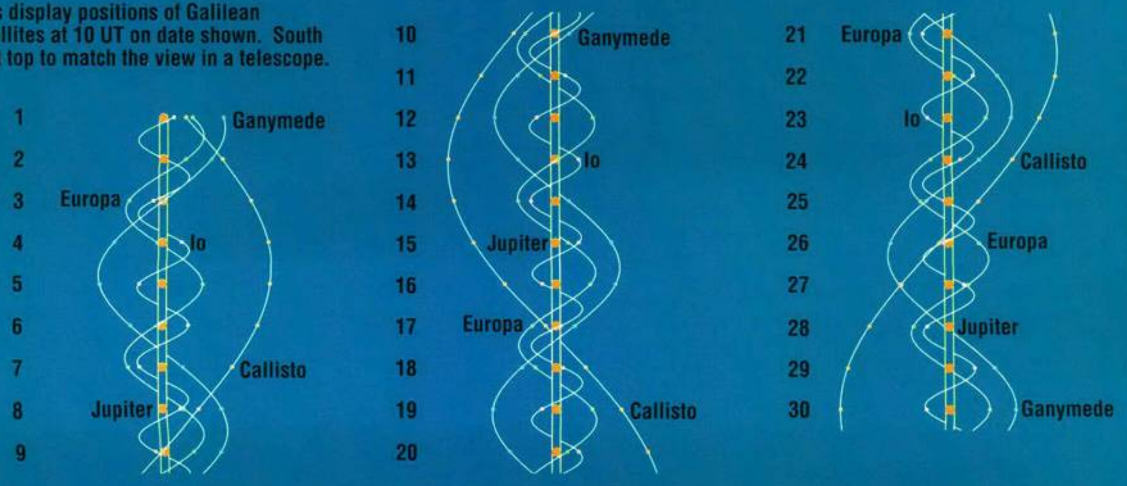


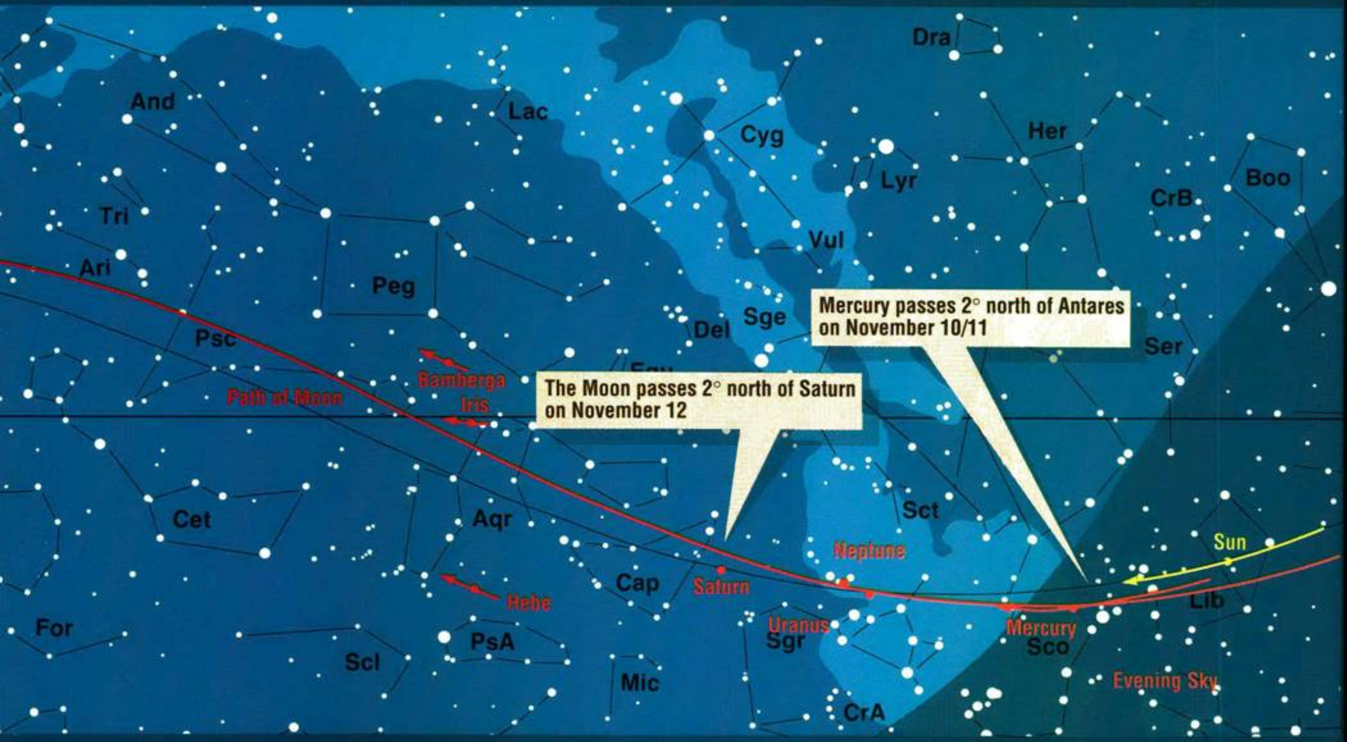


Planet	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	November 1	November 30	November 1	November 30	November 15
Magnitude	−0.3	+0.7	−4.4	−4.2	+1.5
Angular Size	5.1″	8.6″	24.5″	18.6″	3.7″
Illumination	89%	25%	50%	63%	100%
Distance (AU) from Earth	1.306	0.778	0.680	0.896	2.541
Distance (AU) from Sun	0.461	0.330	0.720	0.718	1.553
Right Ascension (2000.0)	15h29.5m	17h34.3m	11h29.8m	13h27.8m	15h11.0m
Declination (2000.0)	−20°48′	−24°31′	3°35′	−6°54′	−17°47′

Jupiter's Moons

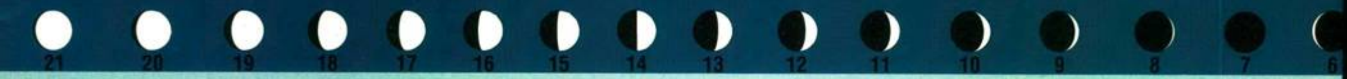
Dots display positions of Galilean satellites at 10 UT on date shown. South is at top to match the view in a telescope.

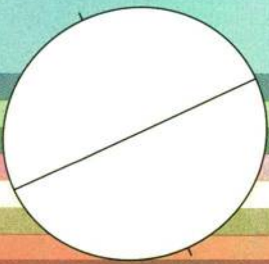


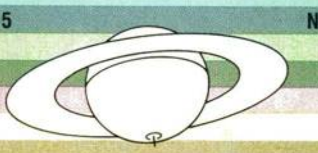


Mercury passes 2° north of Antares on November 10/11

The Moon passes 2° north of Saturn on November 12

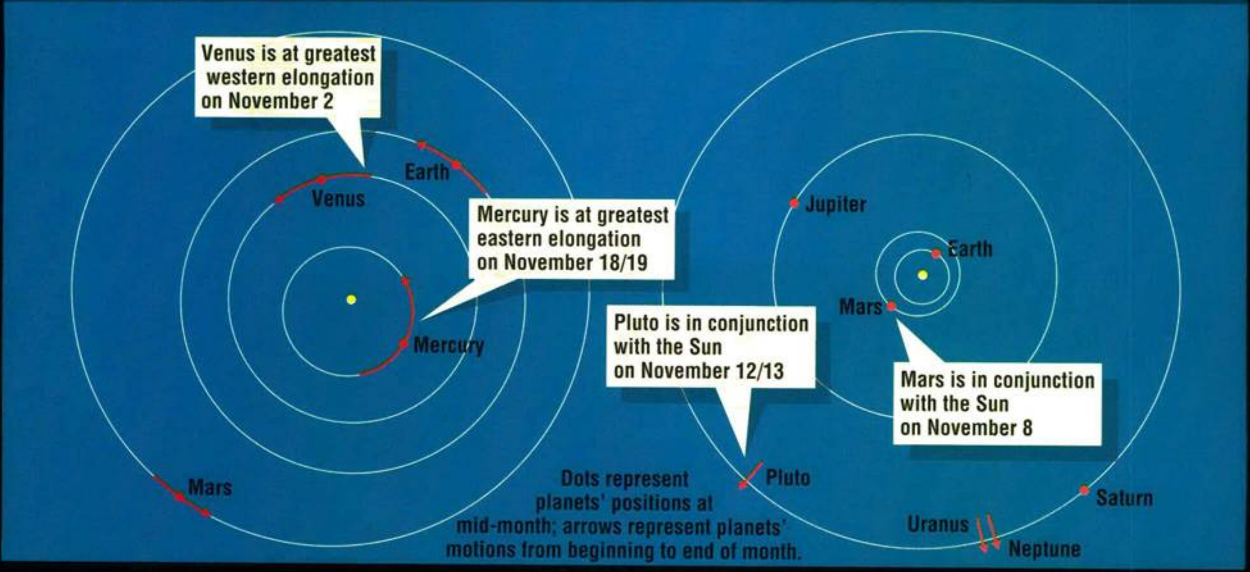






JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
November 15	November 15	November 15	November 15	November 15
−1.9	+0.6	+5.8	+8.0	+13.8
35.0"	16.1"	3.5"	2.2"	0.1"
99%	100%	100%	100%	100%
5.624	10.248	20.135	30.787	30.641
5.377	9.944	19.501	30.196	29.684
10h53.5m	20h16.2m	18h49.1m	19h03.8m	15h27.4m
8°07'	−20°20'	−23°20'	−21°53'	−3°54'

The Planets in Their Orbits



Venus is at greatest western elongation on November 2

Mercury is at greatest eastern elongation on November 18/19

Pluto is in conjunction with the Sun on November 12/13

Mars is in conjunction with the Sun on November 8

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

THE WIDE FIELD OF A NEWTONIAN makes it a great telescope for framing large deep-sky objects such as the North America Nebula (right). The author used a 6-inch f/4.5 reflector combined with 120-format Ektachrome 400 film to produce a photographic field nearly 4° wide. The same combination captured Jupiter near the Pleiades on January 12, 1991 (below). All astrophotos in this article are by the author.

Great Astrophotos: The Newtonian Advantage

Here's expert advice on how to turn this classic and often underrated telescope into a first-class instrument for taking award-winning astrophotos.

by John C. Mirtle

The tried-and-true Newtonian reflector has long offered backyard astronomers the biggest bang for the buck. Newtonians provide generous aperture for a good price. Also, for those seeking a portable telescope for astrophotography, the Newtonian is a good choice. Though neglected by astrophotographers in the last few years in favor of Schmidt-Cassegrains and wide-field refractors, the classic Newtonian is undeserving of such a fate. Its simple and inexpensive optical system offers astrophotographers a lot of advantages.

The photographic speed (f/ratio) of most Newtonians is between f/4.5 and f/7, fast enough that exposure times are short. This allows the use of light-pollution filters or fine-grained films.

With their typical focal lengths of 1,000 to 1,200 mm, 6- to 10-inch Newtonian telescopes will frame most nebulae and star clusters very nicely on 35mm format film, yet still yield a wide field of 1° to 2°. At these focal lengths, using a fine-grained film such as Kodak Tech Pan allows you to take detailed shots of galaxies only a few arcminutes across. Telescopes with focal lengths of 600 to 750 mm (such as a 6-inch f/4 or f/5) provide even wider fields (up to 3° on 35mm film) and allow you to capture rich Milky Way starfields and large deep-sky targets such as the California and North America nebulae.

Of course, one of the biggest attractions of the Newtonian is the price. While refractors designed for astrophotography (such as some of the fast apochromatic models) sell for $1,500 to $3,000 without a mount, a good 6- or 8-inch Newtonian tube assembly can be had for $400 to $800.

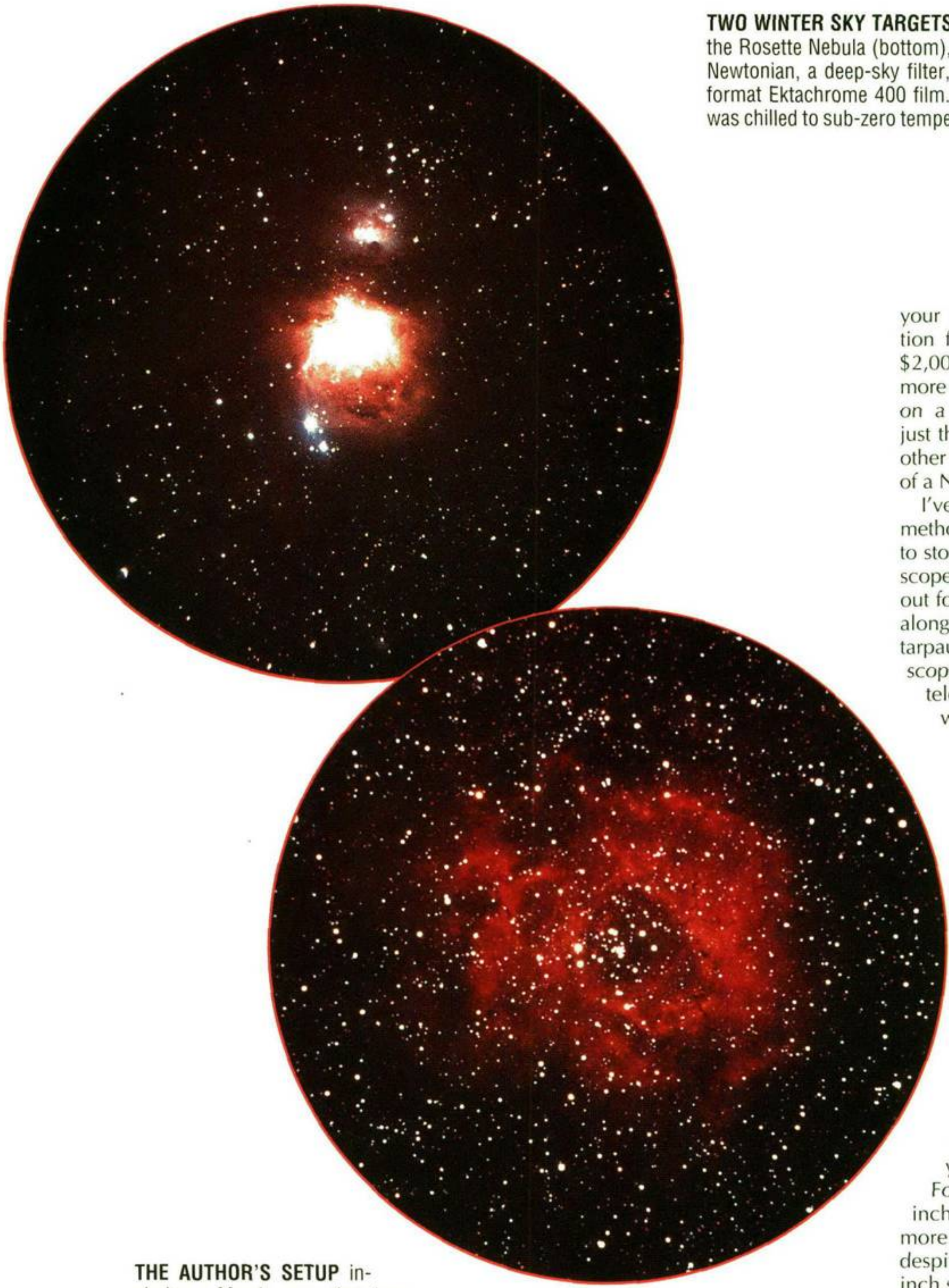
Of the ready-made commercial Newtonians on the market, a few models stand out for astrophotography. I've seen excellent results produced by people using the Celestron SP-C6 and the Meade 8- and 10-inch Research Series models, for example. (The Meade 8-inch Research Series model is now discontinued, replaced by the lighter weight 826C.) The extensive line of 6- to 16-inch Newtonians from Parks also appears to be good, especially when matched to one of Parks' heavy-duty mounts.

Indeed, as with any astrophotography system, it is the mount that is by far the most critical component in a Newtonian setup. A few improvements to the mount and to other components of a typical Newtonian can turn this often-neglected class of telescope into one of the finest instruments for capturing the sky on film.

Upgrading the Mount

My first photographic system was a Meade Deep-Space 16-inch Newtonian. It had an equatorial mount, lots of aperture, a fast f/ratio of f/4.5, and a low price tag. It sounded great. I even managed to get lots of photographs with it that satisfied me at the time. But the big Meade was susceptible to one of the worst enemies of the astrophotographer — wind. The six-foot tube acted like a sail, moving gracefully in the night breezes. In my case, any wind gust more than a few miles per hour would move the telescope enough to produce trailed star images. There are several ways of dealing with this problem.

The most drastic, and expensive, solution is to replace the mounting with a more massive model. There are many excellent mounts on the market from companies such as Astro-Physics, Astro-Track Engineering, Edward R. Byers Co., Epoch Instruments, or Hollywood General Machining. (See the list of suppliers for addresses of these and other companies.) Their mountings are all beautifully made. Any one of them will give



TWO WINTER SKY TARGETS, the Orion Nebula region (top) and the Rosette Nebula (bottom), were recorded using a 6-inch f/4.5 Newtonian, a deep-sky filter, and 40-minute exposures on 120-format Ektachrome 400 film. To increase its sensitivity, the film was chilled to sub-zero temperatures in a special cold camera.

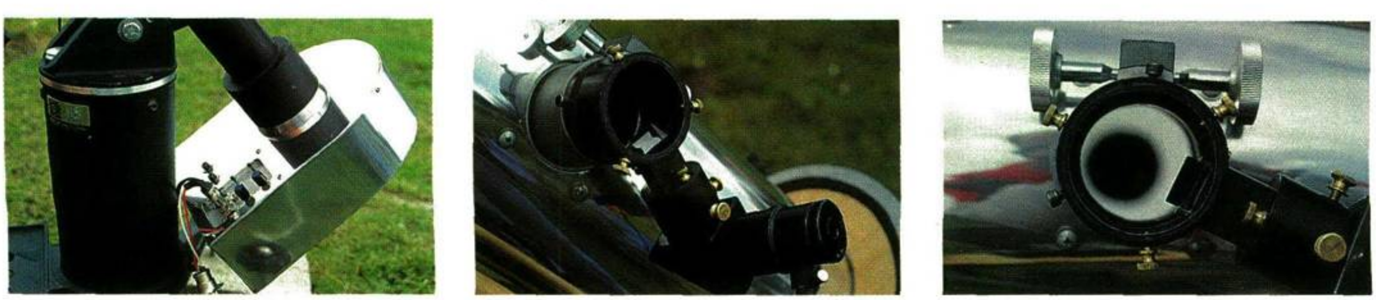
your telescope a rock-solid foundation for fine photos. They also cost $2,000 and up — way up! That's more than most of us want to spend on a complete telescope, let alone just the mount. Fortunately, there are other ways of improving the stability of a Newtonian telescope.

I've found that the cheapest method of dealing with wind gusts is to stop the wind from hitting the telescope in the first place. When I head out for a photographic session I bring along a windbreak. It consists of a tarpaulin stretched across three telescoping tent poles. This keeps my telescope *and me* out of the wind, which makes guiding during long exposures more comfortable.

With my 16-inch scope, the windbreak still wasn't enough on the windiest of nights, so I opted for other solutions. Rather than make the mount bigger, I decided to make the telescope smaller. I now use the Meade mounting primarily with either of two telescopes: an 8-inch f/6 or a 6-inch f/4.5. If your experience is like mine, you'll find using a smaller scope on a mounting originally designed for a larger one will dramatically increase your photographic productivity. For example, I've found my 8-inch photographs frequently show more detail than my 16-inch shots, despite the smaller images the 8-inch scope produces.

Using what in effect was an oversized mounting for the 6- and 8-inch telescopes certainly made a big im-

THE AUTHOR'S SETUP includes a Meade mounting (see previous page) fit with a custom-made drive (below). At right are views of the off-axis guider and its prism; the latter picks off a guide star from outside of the camera's field of view.



provement, but I found that the mounting itself needed an upgrade. The weak link was the clock drive — the motor and gear system that enables the telescope to follow the stars as they move across the sky. As every deep-sky photographer soon discovers, the quality of the main drive gear determines whether or not taking photographs is enjoyable or an exercise in frustration. A drive gear with a periodic error of several arcminutes forces you to keep your eye glued to the guiding eyepiece during the exposure, watching for runaway motions of the guide star. Guiding becomes a tiring task of keeping the guide star centered. Each exposure seems to last forever and, despite your best effort, the resulting pictures often suffer from trailed star images.

On the other hand, a drive gear with periodic error measured in only arcseconds means that you can relax during the exposure. You can be confident that the guide star will not take off across the field, and you can even do some naked-eye astronomy during exposures!

The stock Meade clock drive on the DS-16 served me well for several years. It works great for the visual use it was primarily intended for, but for photography it left something to be desired. I grew tired of paying my guiding dues. I wanted a better drive system. My solution was to replace the stock gears with a new drive gear set from Thomas Mathis Co. I upgraded the Meade 5-inch diameter drive gear to a 9.5-inch gear. Installation involved fabricating a larger mounting plate for the large gear and an adjustable bracket to hold the new drive motor and small worm gear. I also decided to enclose everything with a custom-made aluminum cover. The do-it-yourself effort was worth it — the tracking accuracy is now down to 15 arcseconds and hour-long exposures, while not effortless, are at least not torturous.

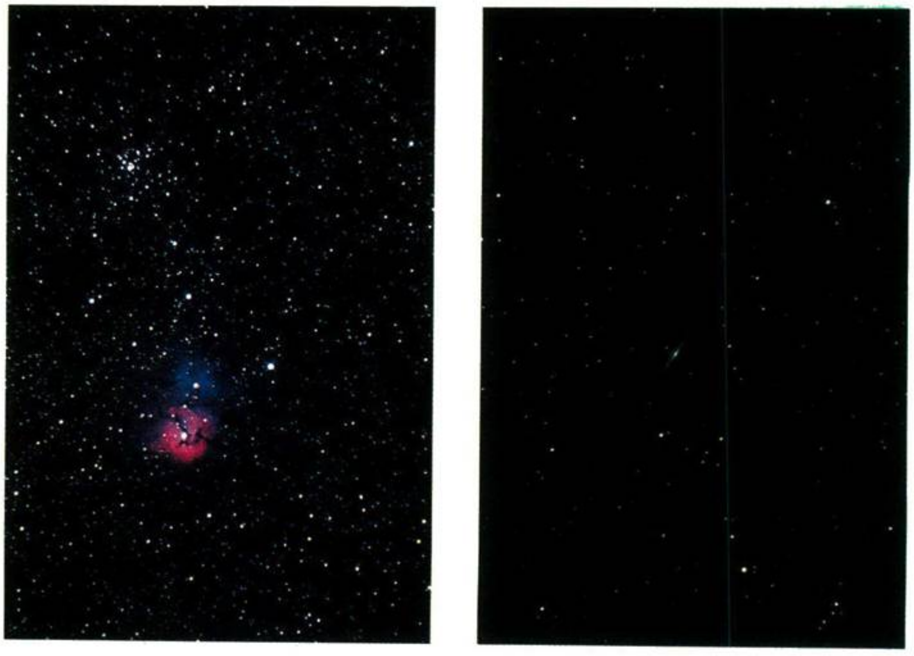
A Sharper Image

After attending to the mount, I found that there were still a few more problems to solve. To my consternation, every once in a while I would get photos in which the star images along one edge of the frame would be either out of focus or suffer from coma — the stars would look distorted.

The coma problem was the result of the way I built my homemade 6- and 8-inch tube assemblies. So that the film frame is fully illuminated, the secondary mirror of a photographic Newtonian is usually oversized and, therefore, fairly heavy. In my case, in both telescopes I was using a flimsy secondary support, and as either telescope moved across the sky during an exposure, the collimation changed. As a result, I ended up photographing a distorted star field at the edge of the main mirror's field of view.

To cure this problem I installed a heavy-duty spider from Kenneth Novak and built a mirror cell as described in *Build Your Own Telescope* by Richard Berry. This mirror cell not only holds its collimation very well but also stops stray light from entering the bottom of the tube. If your preference is to buy a mirror cell, I've found units by Novak are first class.

My original tube was thin-walled Sonotube. But for my homemade Newtonians, I selected insulated aluminum irrigation pipe. Unlike Sonotube,

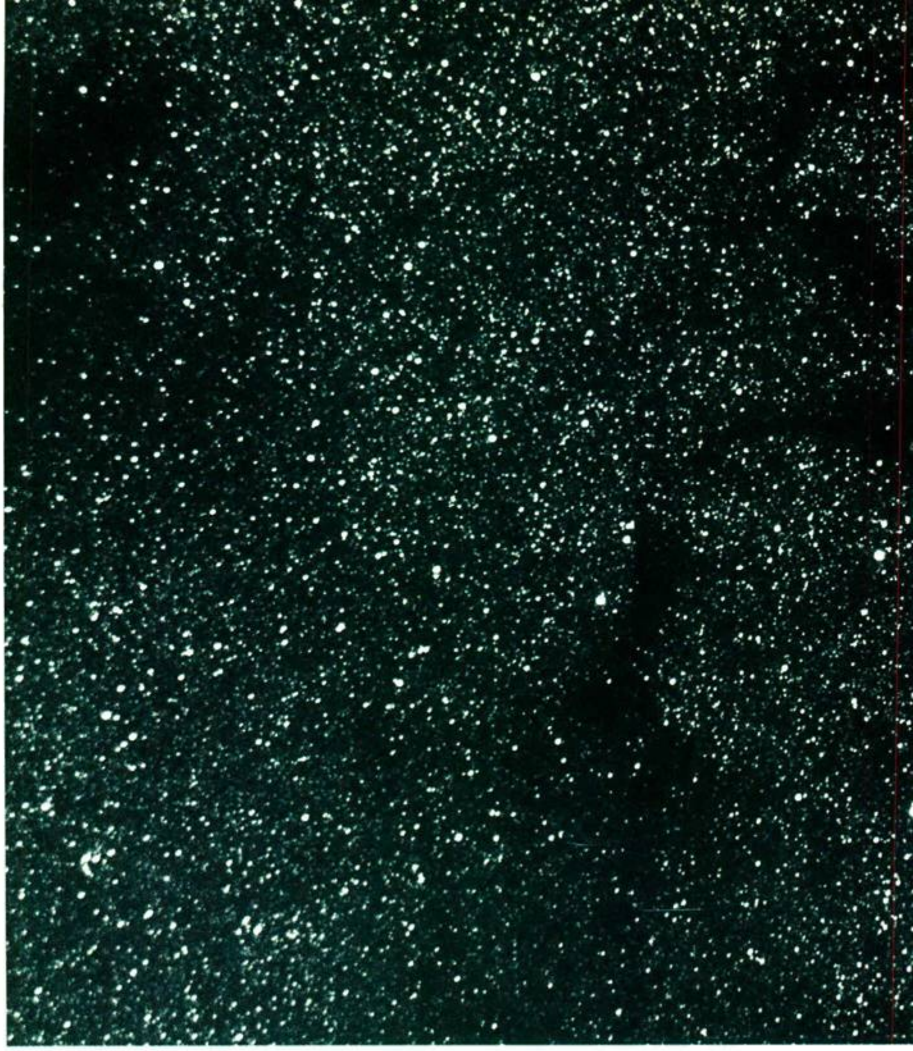


FROM NEARBY NEBULAE to distant galaxies, deep-sky targets abound for the astrophotographer. The California Nebula (top) is seen in a 35-minute exposure using a 6-inch f/4.5 Newtonian. The Trifid Nebula and M21 star cluster (below left) and the edge-on galaxy NGC 4565 (below right) were captured with an 8-inch f/6 Newtonian using 30- and 25-minute exposures respectively. All photos on chilled Ektachrome 400.

COMPANIES TO CONTACT

Here's a list of companies that make equipment and accessories of interest to those assembling an astrophotography system based around a Newtonian.

Astro-Physics, 11250 Forest Hills Road, Rockford, IL 61111, (815) 282-1513. Mounts.
Astro-Track Engineering, 9811 Brentwood Dr., Santa Ana, CA 92705, (714) 289-0402. Mounts.
AstroSystems, Inc., 1536 Meeker Dr., P.O. Box 1183, Longmont, CO 80501, (303) 678-5339. Focusers.
Celestron International, 2835 Columbia St., Torrance, CA 90503, (800) 421–1526. Coma corrector.
Edward R. Byers Co., 29001 W. Hwy. 58, Barstow, CA 92311, (619) 256-2377. Mounts, drive gears.
Epoch Instruments, 2331 American Ave., Hayward, CA 94545, (415) 784-0391. Mounts.
Hollywood General Machining Inc., 1033 N. Sycamore Ave., Los Angeles, CA 90038, (213) 462-2855. Mounts.
Jim's Mobile Industries (JMI), 1960 County Road 23, Evergreen, CO 80439, (303) 277-0304. Drive correctors.
Kenneth F. Novak & Co., Box 69, Ladysmith, WI 54848, (715) 532-5102. Mirror cells, spiders, focusers.
Lumicon, 2111 Research Dr., #5, Livermore, CA 94550, (415) 447-9570. Guiders, coma corrector.
Meade Instruments Corp., 1675 Toronto Way, Costa Mesa, CA 92626, (800) 854-7485. Mounts.
Northern Lites, 640 Cains Way, RR #1, Sooke, B.C., Canada V0S 1N0. Cold cameras, guiders.
Optic-Craft Machining, 33918 Macomb, Farmington, MI 48024, (313) 476-5893. Mounts.
Optical Guidance Systems, 2450 Huntingdon Pike, Huntingdon Valley, PA 19006, (215) 947-5571. Mounts.
Parks Optical, 270 Easy St., Simi Valley, CA 93065, (805) 522-6722. Mounts.
Spectra Astro Systems, 6631 Wilbur Ave., Suite #30, Reseda, CA 91335, (818) 343-1352. Guiders.
Tectron, 2111 Whitfield Park Ave., Sarasota, FL 34243, (813) 758-9890. Focusers.
Tele Vue Optics, Inc., 20 Dexter Plaza, Pearl River, NY 10965, (914) 735-4044. Coma corrector.
Thomas Mathis Co., 830 Williams St., San Leandro, CA 94577, (415) 483-3090. Mounts, drive gears.
University Optics, Inc., P.O. Box 1205, Ann Arbor, MI 48106, (313) 665-3575. Focusers.
Versacorp, P.O. Box 7, Sun City, AZ 85372, (602) 876-8344. Guiders.
Vista Instrument Co., 307 E. Tunnell St., Santa Maria, CA 93454, (805) 925-1240. Drive correctors.
Vogel Enterprises, 38W150 Hickory Court, Batavia, IL 60510, (708) 879-8725. Drive correctors.



the aluminum pipe is solid and holds the optics securely in place.

Nevertheless, I still had focus problems. As it turned out, the focuser was the culprit. To fully illuminate the 35mm film format, the diameter of the focuser should be at least two inches. Unfortunately, most 2-inch focusers on the market use a single set screw to hold the eyepiece or camera in place. I found that when using an off-axis guider, this set screw would push the camera up on one side, putting part of the picture out of focus. The solution was simple — I added two more set screws, 120° apart.

In addition to being at least two inches in diameter, the focuser should also be as short as possible. This avoids vignetting of the corners of the frame. If you are using a full-height focuser, consider chopping off the top or bottom (or both!) of the focuser body. I managed to reduce the height of a 4-inch rack-and-pinion focuser to

THE BEAUTY OF BLACK AND WHITE shows in these views of dramatically different deep-sky objects. At top, the Snake Nebula slithers across a rich field of stars in Ophiuchus. At left, the galaxy M83 exhibits delicate details in its spiral arms. Both photos were taken with an 8-inch f/6 Newtonian on hypersensitized Tech Pan 2415 film. The Snake is a 40-minute exposure, M83 a 60-minute.

1.75 inches and now use it with my 6-inch f/4.5. This telescope will illuminate a 1.75-inch diameter circle on 120-format film with minimal light drop-off at the edges.

If you are not too handy with a hacksaw and file, there are a number of low-profile focusers on the market. For rack-and-pinion models, focusers from AstroSystems, Lumicon, and Tectron work very well. If your preference is the helical design, spend the few extra dollars for the non-rotating type. I used the rotating type for a while and found it to be very frustrating. The problem is that it rotates! So do the camera and the off-axis guider every time you want to check focus. Hollywood General Machining and Lumicon both offer non-rotating helical focusers.

The Guiding Light

When I first decided to give prime focus photography a try, I thought all I had to do was polar align accurately and open the shutter. My first results from the local one-hour photo lab showed me this wasn't the case. To get pinpoint star images with any telescope, Newtonian or not, requires two more things — a guider to monitor the movement of the telescope *and* a means of moving the telescope precisely in both axes.

As with any telescope, deep-sky photography with a Newtonian requires you to compensate for small movements of the image because of atmospheric refraction, polar alignment errors, and drive gear irregularities. To detect these unwanted motions, you need to monitor a star located within a few degrees of the object being photographed. There are two ways of doing this: a separate guidescope (usually a small refractor) mounted piggyback on the main scope or an off-axis guider at the focus of the main scope. Fans of Newtonian telescopes are about equally divided when it comes to choosing a preferred method.

The advantages and disadvantages of each method would make an article by itself. But the biggest drawback of a separate guidescope can sometimes show up in a Newtonian setup — if the tube of the main scope is not strong enough, the guidescope can shift in relation to the main optics as the mount moves the pair across the sky. The result is trailed star images no matter how accurately you guide the photograph. But by ensuring that your main telescope tube is solid *and* by keeping the guidescope weight to a minimum, this "differential flexure," as it's called, shouldn't be a problem. Since switching to the 6- and 8-inch scopes, it's never been a factor for me.

Guidescopes do pose another nuisance for Newtonian users — especially if your mounting is low, say 2 to 3 feet high. The problem is that the guiding eyepiece is at the wrong end! When shooting overhead, sometimes I've had to guide 40-minute exposures while lying on the ground — fine in summer but extremely uncomfortable when lying in a snowbank!

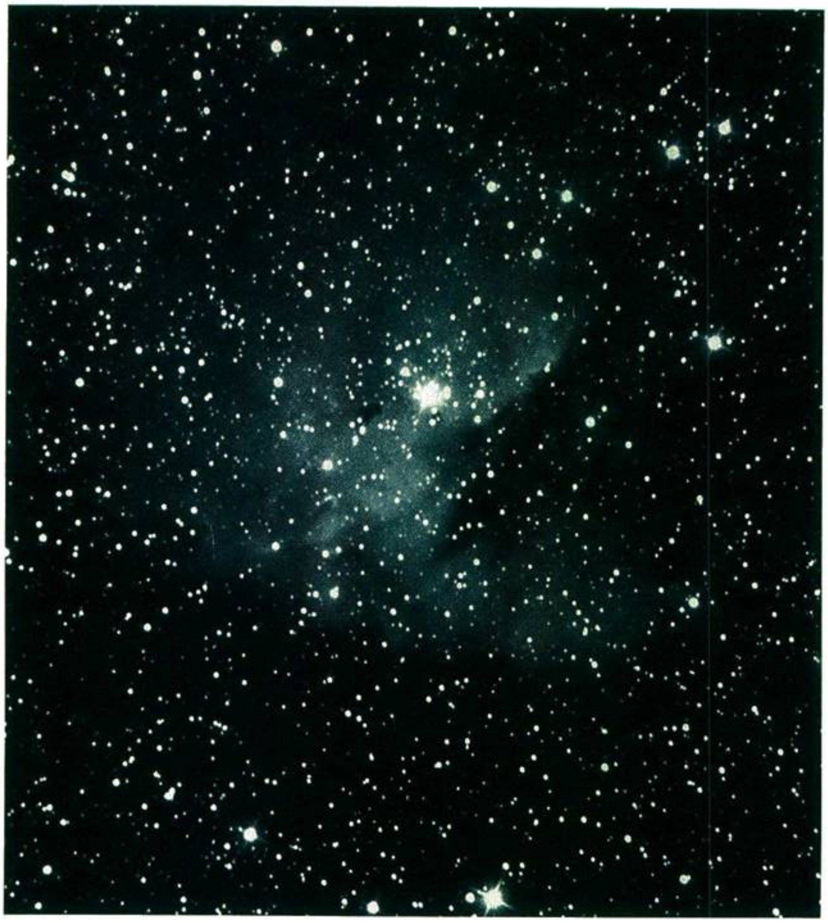
You can avoid this inconvenience by using an off-axis guider. This not only puts the guiding eyepiece at the more comfortable end of the telescope (the top), but also virtually eliminates flexure problems.

An off-axis guider is a small device that sits between the focuser and camera, acting as a beam splitter. The guider has a small prism that juts into the edge of the light path, picking a star off the edge of the field for you to guide on.

The two biggest complaints with off-axis guiders are the poor optical quality of the guide star images and the limited number of guide stars to choose from. I have always used an off-axis guider with my 8-inch and have never had to pass up photographing an object because I couldn't find a star bright enough to guide on. But there's no question about the other complaint — the optical quality of the guide star *is* poor. This is because the prism is taking light from the edge of the field where all fast Newtonians exhibit coma. Instead of guiding on a round starlike image, you are left with an asymmetrical blob. Once you get used to it, blob guiding works just fine.

My preference when shooting 35mm format is the off-axis guider. To me, the advantages of comfortable, flexure-free guiding, plus the light weight of the guider, make it more appealing than a guidescope. The guider make by Lumicon has been available for several years and is probably the most popular on the market. It's the one I use, but new models designed for Newtonians are now available from Spectra Astro Systems and Versacorp.

THE POWER TO PROBE deep into space with astrophotography can be achieved even with a small- or medium-aperture telescope. At left, author John Mirtle captured the 9th-magnitude galaxy NGC 7331 in Pegasus surrounded by several of its faint companion galaxies. Below it is the cluster of 15th-magnitude galaxies known as Stephan's Quintet. At right is a seldom-observed nebula in Cassiopeia, NGC 281, also called the Pacman Nebula. Both photos are 60-minute exposures on hypered Tech Pan film using an 8-inch f/6 Newtonian.



But when I shoot with medium-format 120 film, I switch to a guidescope — the prism in the off-axis guider would cast a large shadow on the picture with this format film.

Black Boxes

For anyone with a telescope that employs AC motors, an electronic black box called a drive corrector is an essential accessory. These devices are available as single- or dual-axis units. A single-axis unit will allow you to speed up or slow down the R.A. motor to make guiding corrections. A dual-axis unit will allow you to move the telescope in declination as well, provided your declination axis is equipped with a suitable motor. For Newtonian telescopes, this is the preferred option. Depending on the size of the telescope and the mount, manual slow-motion controls can be difficult to reach from the guiding eyepiece, making electric slow motions controls preferable.

If you are considering a dual-axis corrector, I highly recommend one with a "declination reverse" option. This is useful because when you flip the tube from the east side of the mount to the west, the button that used to slew the scope north now moves it south, and vice versa. At 4 a.m. it is easy to forget this and move the telescope the wrong way. A declination reverse switch allows you to ensure that the same button always moves the scope in the same direction.

Telescopes equipped with DC stepper motors usually come with a single-axis drive corrector in the form of a simple hand controller. Dual-axis versions are sometimes offered as an option — you simply need to add the declination motor. One of the nice things about stepper motor drives is that they run directly from batteries. This gives you complete freedom from 110-volt sockets, car batteries, and long, trailing power cords. On the other hand, not all of the DC-drive hand controllers have a declination reverse switch (the Super Polaris mounts, for example, lack this).

What about Coma?

The big benefit of Newtonians is their combination of fast photographic speed, wide field, and low cost. The big disadvantage is coma. Coma is an optical aberration that turns stars at the corners of the photograph into cometlike smears. The faster the focal ratio, the more pronounced the effect. With an f/6 system the central 24mm of a film frame will be coma-free. This may be good enough that you won't have to worry about coma at all. With an f/4.5 scope, however, the coma-free circle shrinks to 15mm. How much coma at this or any f/ratio bothers you depends on your standards and on what you intend to do with the negatives or slides. If your astrophotos end up as 3.5- by 5-inch prints, coma at the corners of the frame may not be noticeable. If you shoot high-resolution Kodak Tech Pan film and enlarge the negatives to 11- by 14-inch prints, you will probably find coma offensive.

For decades, amateur astrophotographers simply accepted coma as the price you paid for the low cost of Newtonian optics. In the last few years, manufacturers have introduced coma correcting lenses. These are available from Celestron, Lumicon, and Tele Vue (their ParaCorr). I use the Lumicon model — it is easy to use, as it threads directly onto their off-axis guider to ensure correct spacing to the film plane. In addition to reducing coma on the photograph, these correctors also reduce coma in the guide star, making guiding that much easier.

Today, coma correctors are essential equipment for astrophotographers seeking to extract the finest photos from their Newtonians. These devices and the many other accessories and high-quality mounts available on the market today can turn the neglected Newtonian into a powerful astrophotography tool.

True, as with any telescope, shooting prime focus with a Newtonian is a bit more involved than just polar aligning and opening the shutter. But with today's equipment and films it has never been easier to get into astrophotography, and the Newtonian provides one of the most economical routes. ☐

John C. Mirtle has been doing astrophotography with various Newtonian systems for about five years and is an active member of the Calgary Centre of the Royal Astronomical Society of Canada.

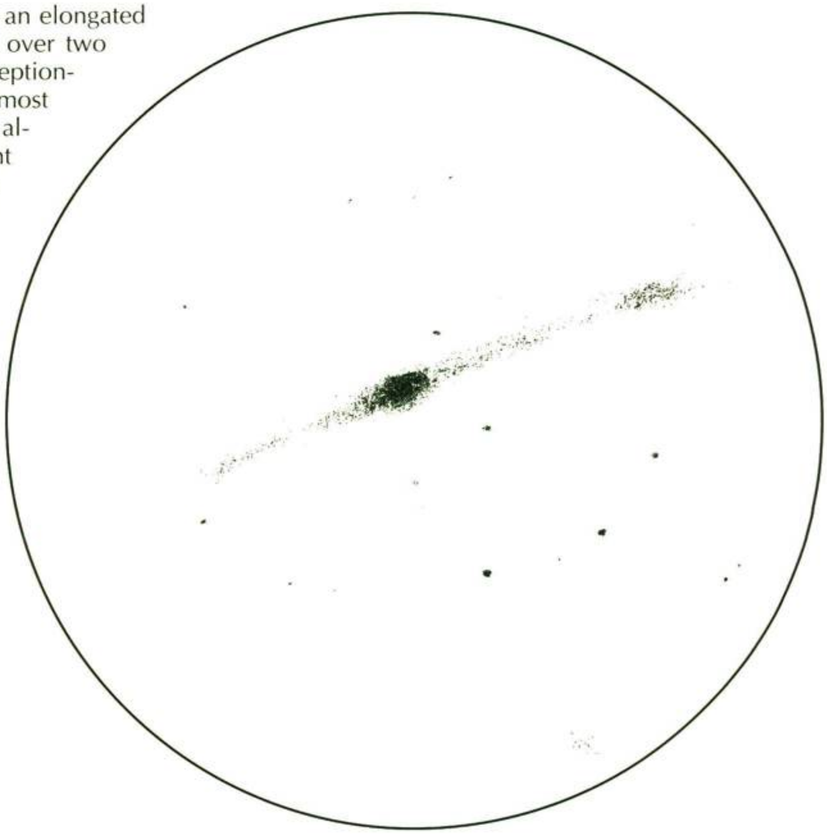
THE BACKYARD ASTRONOMER

Observing the Andromeda Galaxy

The great spiral in Andromeda offers it all to galaxy observers — dust lanes, a concentrated nucleus, star clouds, globular clusters, and a bevy of unusual satellite galaxies.

by Alan Goldstein

It is visible on dark autumn nights as an elongated smear of gray-green light stretching over two diameters of the Moon. Under exceptionally transparent skies it appears almost three-dimensional: a softly glowing almond hanging far above the bright Square of Pegasus. It is the single most distant object visible to the naked eye, the Andromeda Galaxy. This nearby spiral galaxy — a twin of our own Milky Way in the Local Group of galaxies — lies 2.2 million light-years deep into the night sky. Its light, visible on any clear night from late summer to early spring, shows us the nearby spiral as it appeared 2.2 million years, about 1/100 of a galactic year, ago.



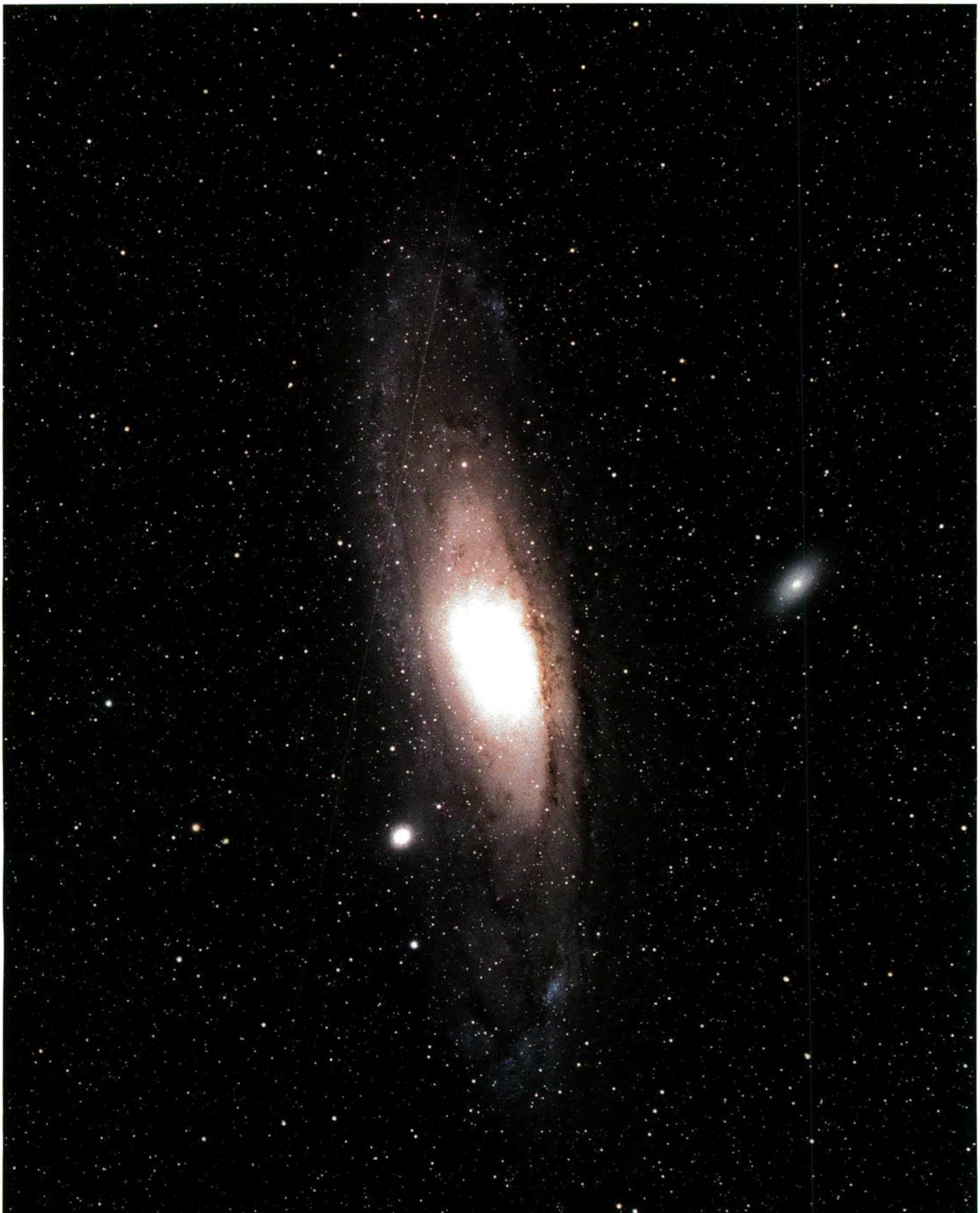
M31, M32, and NGC 205 6-inch reflector at 30x
Sketch by Jeffrey Corder

Viewing the Galaxy

How much of the **Andromeda Galaxy** (M31, NGC 224) can you see with the naked eye? Under very dark, transparent skies you can trace the extent of the galaxy's arms to about 3° across. (Remember, the diameter of the Full Moon is only one-half degree.) The slightest optical boost such as that given by low-power binoculars will make the oval shape immediately conspicuous. The galaxy appears much brighter in binoculars. Try to determine where M31 ends and the night sky begins — it's nearly impossible. While the light from the galaxy eventually blends into the background light of the sky, the gravitational pull of the Andromeda Galaxy extends across the Local Group. Its presence influences, at least on a small scale, our own Galaxy. M31 more directly holds in its gravitational embrace four satellite galaxies visible in backyard telescopes. We'll examine these shortly.

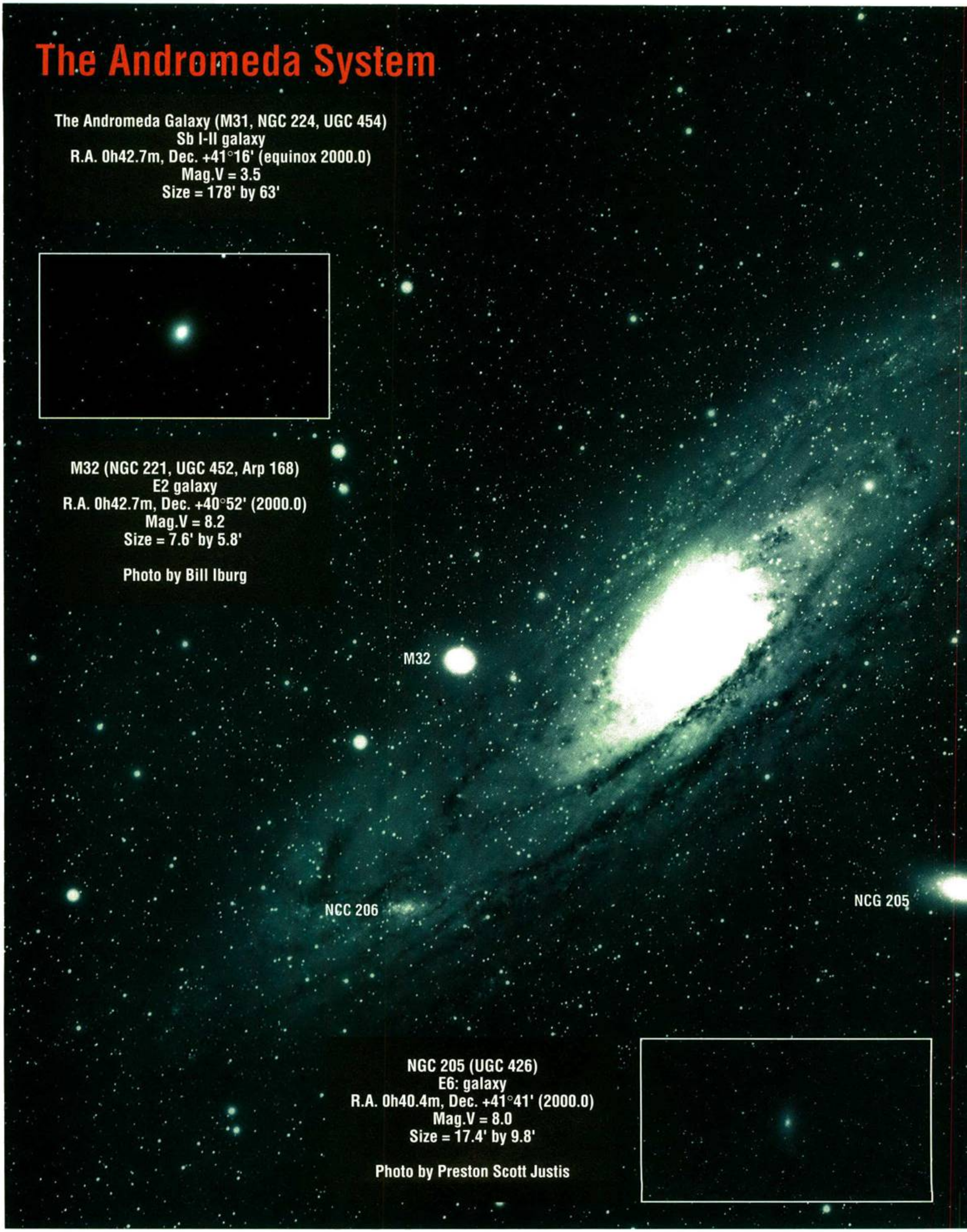
What does this cosmic neighbor look like when viewed from the backyard? A small telescope shows a bright central hub surrounding M31's nucleus. The galaxy's faintly visible spiral arms form a ghostly glow around the bright hub. A long focal length telescope reveals the glow of the spiral disk against an inky black sky. Those of you with 6-inch to 10-inch scopes will find a glorious view awaiting. You will see streaks of dark, star-obscuring dust, a bright, ball-like nucleus, and a single bright star cloud.

M31's nucleus may be seen as a small fuzzy stellar patch in the center. It bears magnification well because of its high surface brightness. The heart of the Andromeda Galaxy beats with the light of hundreds of thousands of stars packed into a volume no larger than that containing the nearest stars. Inhabitants of this region would live under a "night" sky full of stars, each with the brightness of the Full Moon.



The Andromeda Galaxy
Mag. 3.5 Size 178' by 63' by Tony Hallas and Daphne Mount

The Andromeda System



The Andromeda Galaxy (M31, NGC 224, UGC 454)
Sb I-II galaxy
R.A. 0h42.7m, Dec. +41°16' (equinox 2000.0)
Mag.V = 3.5
Size = 178' by 63'

M32 (NGC 221, UGC 452, Arp 168)
E2 galaxy
R.A. 0h42.7m, Dec. +40°52' (2000.0)
Mag.V = 8.2
Size = 7.6' by 5.8'

Photo by Bill Iburg

NGC 205 (UGC 426)
E6: galaxy
R.A. 0h40.4m, Dec. +41°41' (2000.0)
Mag.V = 8.0
Size = 17.4' by 9.8'

Photo by Preston Scott Justis

NGC 185 (UGC 396)
dE0 galaxy
R.A. 0h39.0m, Dec. +48°20' (2000.0)
Mag.V = 9.2
Size = 11.5' by 9.8'

Photo by Jack Newton

NGC 147 (UGC 326, DDO 3)
dE4 galaxy
R.A. 0h33.2m, Dec. +48°30' (2000.0)
Mag.V = 9.3
Size = 12.9' by 8.1'

Photo by Jack Newton

Andromeda's Observing Challenges

- ☐ bright, ball-like nucleus
- ☐ oval galactic hub
- ☐ spiral arms
- ☐ dust lanes in arms
- ☐ star cloud NGC 206
- ☐ globular clusters
- ☐ satellite M32
- ☐ satellite NGC 205
- ☐ satellite NGC 147
- ☐ satellite NGC 185
- ☐ nova searching
- ☐ supernova searching

With an 8-inch or larger scope, the most visually interesting feature in M31 is the dark nebulosity surrounding the brightest spiral arms. The foreground portion of the spiral disk will be discernible from the dark lanes. The dust lanes that are easiest to see lie in front of the central hub.

Large Telescope Challenges

Large backyard scopes (12 inches and more aperture) pull in more light, but at the expense of a smaller "window" to look through. Instead of observing the galaxy as a whole, you must look at it piecemeal. While small telescopes can pick out dark nebulae, larger instruments can show brighter condensations of light. Apparently less aperture is necessary to see areas where there are fewer stars than areas where there are more stars! (Actually the dark nebulae are substantially larger than the stellar associations, clusters, and emission nebulae that create the bright portions of the galaxy's spiral arms.)

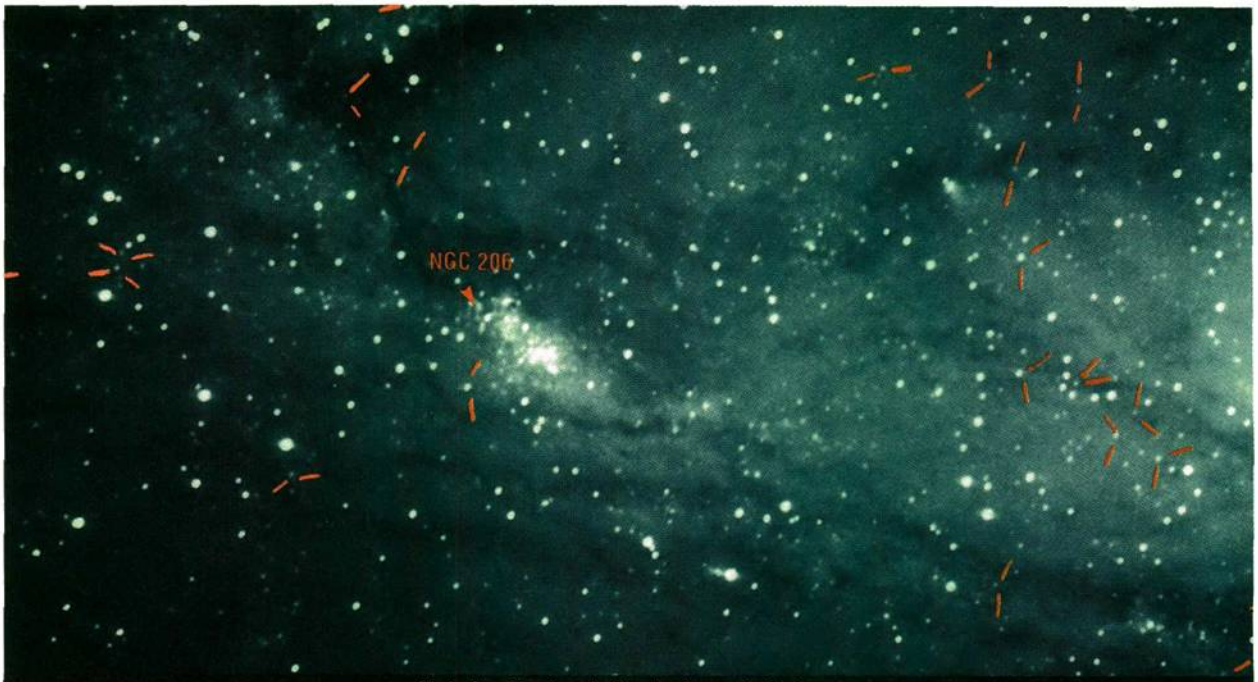
The Andromeda Galaxy does contain one massive concentration of stars that is comparable in size to some of the large dark nebulae. **NGC 206** is an extremely large cloud of young, hot stars and glowing nebulosity that measures thousands of light-years across. Under excellent skies, NGC 206 can be seen with averted vision in telescopes as small as 6 inches in aperture. It is easier to pick out in larger rich-field telescopes — knowing where to look is half the battle (see the photos at left and on page 80).

Other challenges await large telescope observers. Searching for novae in the central area of M31 might make a nice challenge. Within a 15' radius of the nucleus, Halton C. Arp found as many as 30 novae during a year and a half of photographic patrolling. Such novae may brighten to 15th magnitude, and nightly monitoring may reveal one or two each month. The sheer number of foreground stars will make the task difficult at first, but a good large-scale photo like the one at left will help you spot the transient interlopers.

Other luminous stars lie just beyond the visual range of large telescopes. These stars can be resolved photographically with the large telescopes and hypered fine-grain film available to many of today's amateur astronomers. Individual Cepheid variables, first used by Edwin Hubble to determine the distance of the Andromeda Galaxy, are beyond the range of all but the largest amateur telescopes. Using charts developed by astronomers (such as the *Atlas of the Andromeda Galaxy* by Paul Hodge), amateur astrophotographers will be amazed at the vast amount of detail that can be resolved using state of the art deep-sky photographic techniques.

The challenge of supernova hunting lies in exercising patience more than anything else. The last supernova, given the variable star designation S Andromedae, blazed up to brighter than 6th magnitude in August 1885. It was not observed until a few days after maximum. S Andromedae was located near the nucleus. Because of the high density of stars in that region of the galaxy, other supernovae are likely to be seen there as well. It is unlikely that the next supernova in M31 will be found after it peaks in brightness. The challenge for an observer will be to see and report it first.

The Andromeda Galaxy is full of other interesting



Globular Clusters in the Andromeda Galaxy
by Paul Roques

features. For dedicated observers looking for something different, M31 offers a splendid array of globular clusters. Granted, most of these objects require large telescopes to be seen. They are too distant to be seen as anything more than faint stars, the brightest glowing between magnitudes 12 and 13. See the photo above, which will serve as an excellent finder chart for many of the brightest globulars in M31.

The Andromeda Satellites

Astronomers know of eight major satellite galaxies belonging to the Andromeda Galaxy. Half of these are too faint to be picked up with amateur telescopes. The other four are well known and, although low-mass objects, are visible without difficulty in small telescopes.

M32 (NGC 221) and **NGC 205** are dwarf elliptical galaxies. Both are small and contain just a small fraction of the stars of their larger spiral companion. They consist primarily of old stars with a preponderance of stars in the cool end of the spectrum. Physically the two galaxies differ only in shape. There are more similarities than differences. Yet, these two objects do not appear identical in a telescope. Why?

One characteristic of a galaxy that is determined by telescopic observation is the surface brightness. This is the amount of light measured in a given unit of area in the sky. The surface brightness is more difficult for observers to comprehend than the simple magnitudes used to measure starlight. As a measure of a galaxy's brightness, surface brightness is more meaningful than magnitude because it takes into account the galaxy's size and brightness. A galaxy that is 8' by 5' may have the same integrated magnitude as a 10' by 8'; yet comparing the two galaxies, the larger one will appear fainter. This is because the light is spread over a larger area. It is fainter per square arcminute than the smaller galaxy.

In the Andromeda system, M32 and NGC 205 appear different because NGC 205 has a lower surface brightness. It is possible that the stellar density is lower. With approximately the same number of individual stars spread more thinly over a larger area, the galaxy will appear dimmer. It is for the same reason that the arms of Messier 31 are more difficult to see than the central hub. (There is also more dark nebulosity which obscures much of the starlight in this or any other spiral system.)

The closest companion to M31 is M32, the brightest satellite galaxy. It is a dwarf elliptical (E2), with a high surface brightness. Glowing at 8.0 magnitude, M32 can be seen in large binoculars under good dark skies and appears to be embedded in the glow of the larger spiral galaxy. M32 covers a relatively large area of the sky compared with most galaxies (7.6' by 5.8' in diameter), because it is so close. At the distance of some of the galaxies in the Virgo cluster (some 50 million light-years away), a galaxy of M32's physical size would appear very tiny and extremely faint.

Deep-sky gazers may see M32, but many observers overlook it as they seek the grandeur of the Andromeda Galaxy. This galaxy warrants closer scrutiny. While it does not offer the detail available in its larger neighbor, M32 does show a stellar nucleus without a conspicuous central hub. Under very black skies, with the proper equipment, the boundary between this and the larger spiral galaxy is indeterminate and the starlight from both intermingle. M32 lies suspended in front of the giant wheel of stars that gravitationally holds it close.

NGC 205 is sometimes called M110 because Charles Messier did observe it, although he didn't assign a number to NGC 205. This galaxy's visual magnitude is 8.2, but it is more difficult to see than M32 because of its low surface brightness. Its glow is spread over an area of 17.4' by 9.8', nearly four times that of

M32. The result is a deceptively dim galaxy.

NGC 205 is peculiar in that it has several dark dust patches near its center. Not surprisingly, there are a few relatively young blue stars associated with this dust. This is because much of this dust is being compressed by gravity to form new stars. Most elliptical galaxies formed billions of years ago with very little additional new star development. The dark patches are difficult to see visually.

NGC 205 can be seen with binoculars under dark skies. In small telescopes it appears as an elongated glow with a just a slight brightening toward the center. Larger instruments show a brighter central core, but there is no condensed nucleus like M31 or M32. How well can you see NGC 205 under suburban light-polluted skies?

The 15th-magnitude globular cluster designated "G73" belongs to NGC 205 rather than the Andromeda Galaxy. It should be visible with a 6-inch telescope under excellent skies, though a finder chart will be necessary to distinguish it from the many other faint foreground stars in this area.

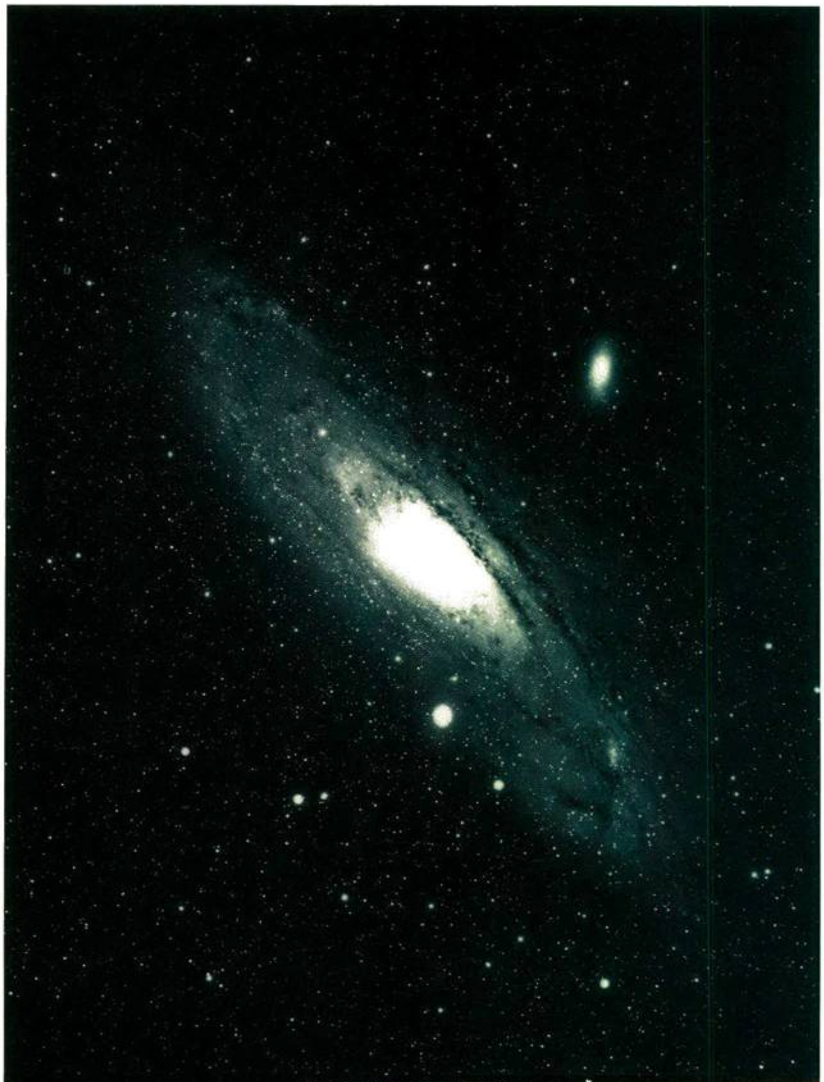
If you don't find the Andromeda Galaxy's neighboring companions much of challenge, I am not through. Lying 6° to the north, in Cassiopeia, lie two more galaxies gravitationally bound to the Andromeda system. **NGC 147** and **NGC 185** have surface brightnesses comparable to that of NGC 205, although they are somewhat smaller and at least a full magnitude fainter. Be sure you can see NGC 205 quite easily before attempting to observe either galaxy.

NGC 147 and NGC 185 can be found by star hopping west of Omicron Cassiopeiae. NGC 185 lies 1° west of Omicron and is the brighter of the two at 9.5 magnitude. NGC 185 is a dE0 galaxy that measures 11.5' by 9.8' across, making it visible in a 6-inch telescope under very dark skies. Like NGC 205, this compact galaxy has several small dark patches that contain young blue stars, indicating a minor burst of star formation.

NGC 147 lies a degree west of NGC 185. It glows softly at 9.5 magnitude. With a diameter of 12.9' by 8.1', this dwarf E4 galaxy is considerably more elongated than neighboring NGC 185. NGC 147 has a lower surface brightness and requires very dark skies — moonlit or light-polluted skies will make observing this galaxy difficult. Save this galaxy for really dark skies. Once you become familiar with them, try again under less than ideal conditions and notice how difficult they become!

The Andromeda Galaxy and its companions offer skygazers a choice of observing challenges varying from using the naked eye to the largest telescope money can buy. You can simply sit out in the cool, crisp autumn nights and gaze up at the most distant object visible to the eye, daydreaming about what your own neighborhood would have been like over two million years ago.

Or if you like challenges, the Andromeda system provides a veritable potpourri of choices. You can test your ability to pick up low-surface-brightness objects like NGC 147, NGC 185, and NGC 205. You can look for spiral arm structure and dark lanes in M31. You can search for the tiny globular clusters swarming around M31 like bees around a hive. Or you can sit back, relax and soak up the Andromeda Galaxy's beauty just for the pure pleasure of stargazing. Never have so many observers had such a wonderful set of decisions to make. □



The Andromeda Galaxy
Mag. 3.5 Size 178' by 63' by Bruce D. McDonald

Alan Goldstein is national coordinator of the National Deep Sky Observers Society, a nonprofit group of observers, and a contributing editor of Deep Sky *magazine. He resides in Louisville, Kentucky.*

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- If Official Entry Form is missing from this magazine, send a postcard with this magazine's issue date and the name of the store where you purchased your copy to: ASTRONOMY Sweepstakes, P.O. Box 1612, Waukesha, WI 53187-1612. Cards must be postmarked by the last day of this month.

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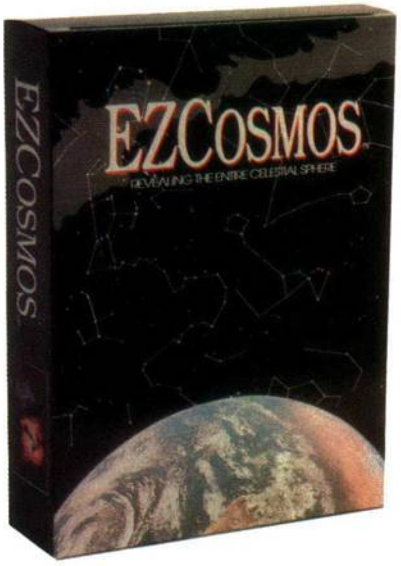

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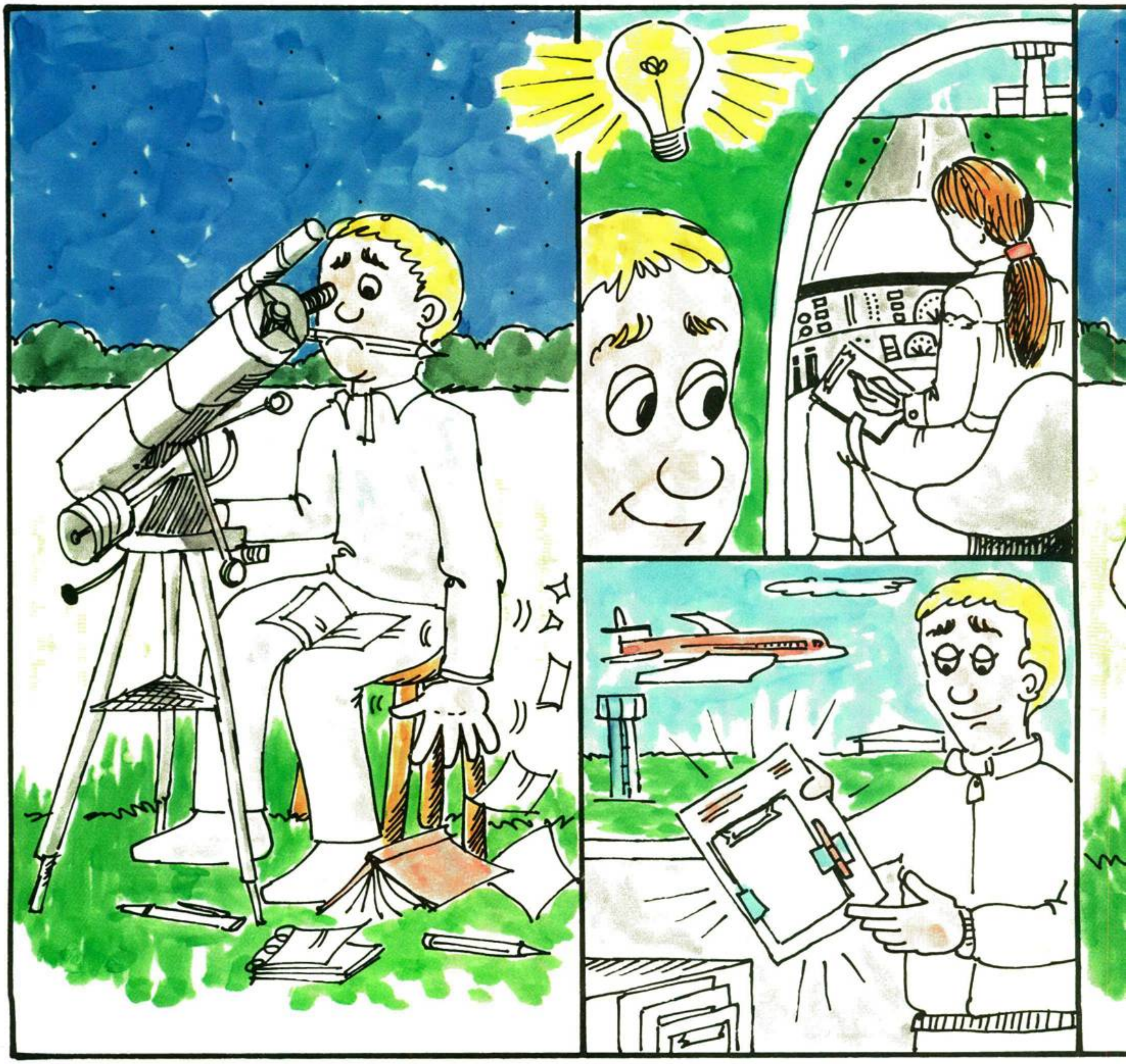
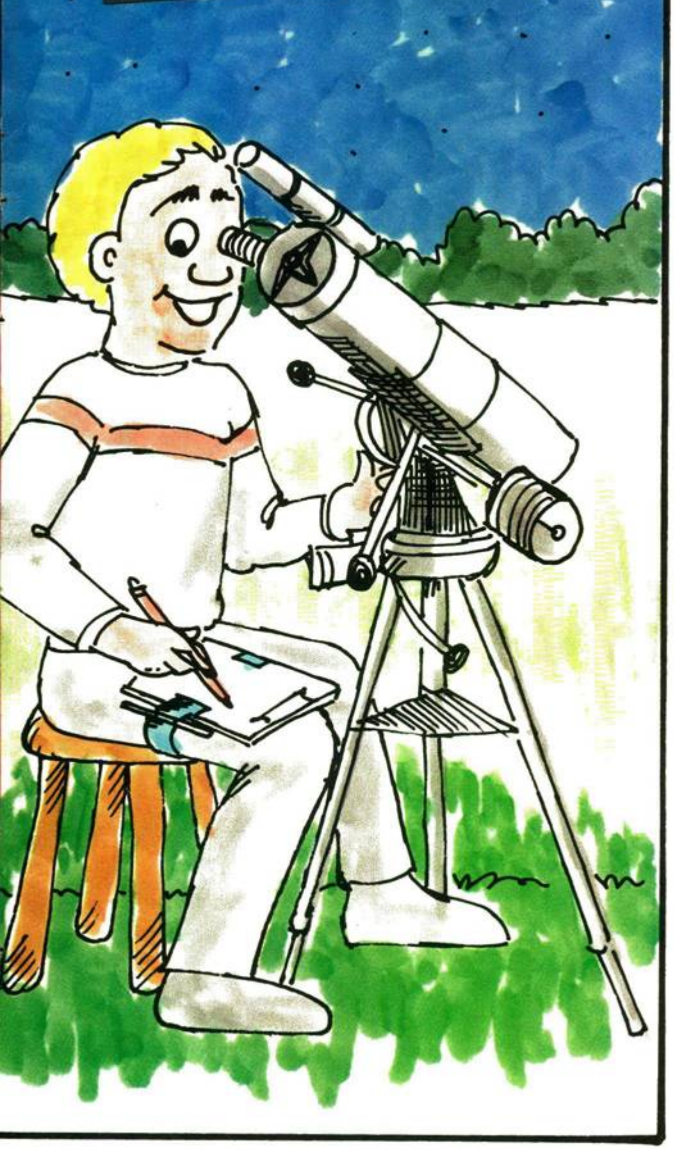
An Observing Desk On-the-Go

When you're seated at the telescope, a pilot's kneeboard can serve as a lightweight portable desk in the dark.

by Lawrence R. Smith





If you've ever tried making sketches or writing notes at the eyepiece, you know the problems. The wind blows your papers everywhere. You can never find that favorite drawing pencil in the dark. Setting up a flat drawing surface means lugging a table around with you. Holding a notebook in one hand and a pencil in the other leaves you wishing for a third hand to hold the flashlight, not to mention to focus and move the telescope.

Well, here's a simple idea that I've found works very well for keeping things organized and convenient at the eyepiece. It's called a pilot's kneeboard. It is a clipboard that a pilot straps to one leg to form a convenient desk surface. It will not slip or fall off and can hold pencils and colored markers, pads, and sheets of report paper.

First used by Air Force pilots, kneeboards were so popular they found their way into general aviation. Kneeboards are only about 6-by-9 inches. They can be used by anyone, tall or short, left- or right-handed. Constructed of lightweight aluminum, kneeboards are held in place on the upper leg with Velcro straps. (Some types use an elastic belt that can become too tight.) Even if you stand or walk around, the kneeboard stays on your leg. This allows you to move about, adjusting your telescope, without spilling pencils or papers. When you sit down again, everything is right where you need it to continue your drawing or note taking.

You'll find kneeboards sold at almost any airport that offers flying lessons to the public. These small civil aviation airports always welcome visitors, and they usually have a retail bookshelf or display case of products. They offer pilot's accessories such as logbooks, training manuals, sunglasses, special flight maps, and kneeboards. Prices for kneeboards range from $20 to $50.

More expensive models have tiny gooseneck lamps that can be tinted red to prevent night vision loss. Some models have falling pockets on both sides of the leg. They act like saddle bags extending all the way to the ground. Pockets with plastic cover sheets are perfect for storing star maps and alignment charts. Those with zippered pockets can be used for eyepieces, filters, or Barlow lenses.

If you can't find a kneeboard in your area, call one of these national aviation mail order suppliers: Aviation Book Company, 25133 Anza Drive, Santa Clarita, California, (805) 294-0101, or Sportsmans Market Incorporated (Sporty's), Box FTM, Clermont County Airport, Batavia, Ohio, 45103, (800) LIFTOFF.

One model I like is the $29.95 tri-fold cloth model from Aviation Supplies and Academics (available from most sales outlets). It provides a removable center section with a tooled aluminum surface. Two side panels of black cordura-like material frame clear plastic-covered pockets. With one fold, a page from ASTRONOMY magazine will fit in these pockets and remain visible, making it easy to search the sky for deep-sky targets. The pocket flaps themselves form a wide, even wrap that keeps the kneeboard in place without constricting blood flow to the leg.

In fact for $30, this kneeboard has proven to be one of the most useful and least expensive accessories I own. It has helped me improve the accuracy and appearance of my astronomical logbook. Now I spend more of my time under the stars actually looking *at* the stars and not searching for a fallen pencil that has rolled out of sight across the patio floor. ☐

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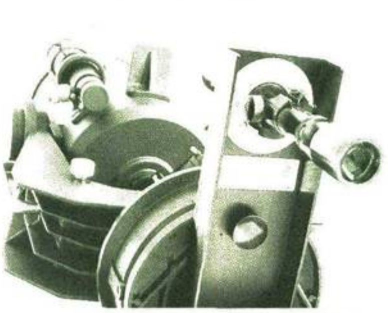

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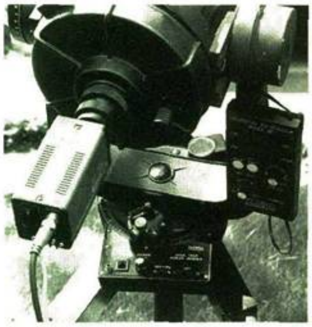

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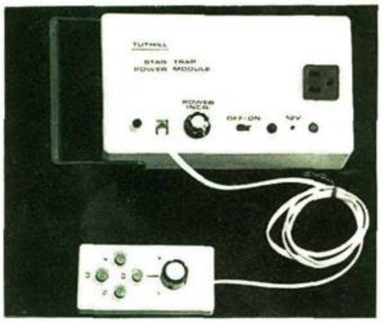

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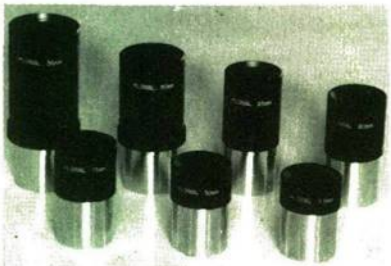

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These two new low-profile helical thread mounts stand only about 1-1/2" high. These are all aluminum construction and each unit has been hand fitted for an oil smooth thread fit. The 2" Vega-3 model is the perfect replacement unit for 1-1/4" devices found on some Dobsonian telescopes. The **2" Vega-3** is priced at **$54.00.** Add **$10.95** if you need a **1-1/4" adapter.** The smaller **1-1/4" Vega-5 is $36.95**

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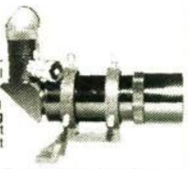

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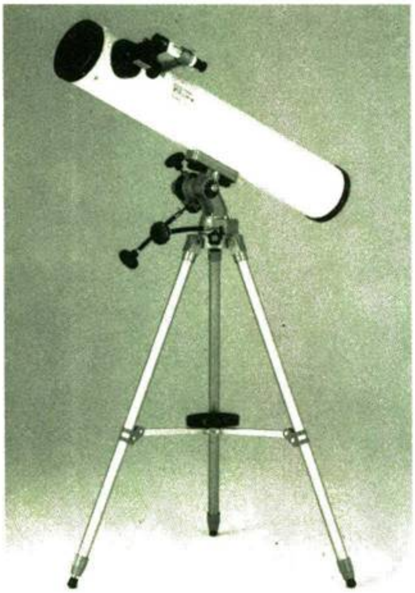

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4½″ Newtonian Alt-Azimuth Mount

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- 2 eyepieces
  - 18mm (50x)
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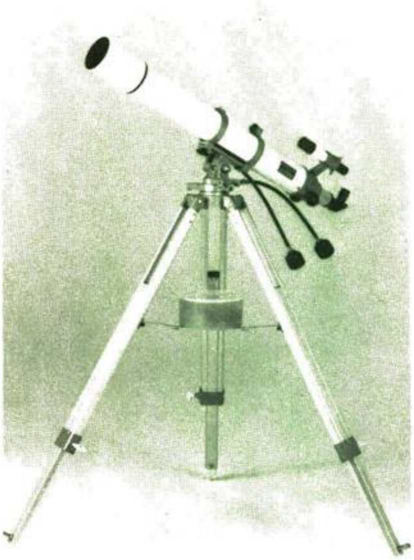

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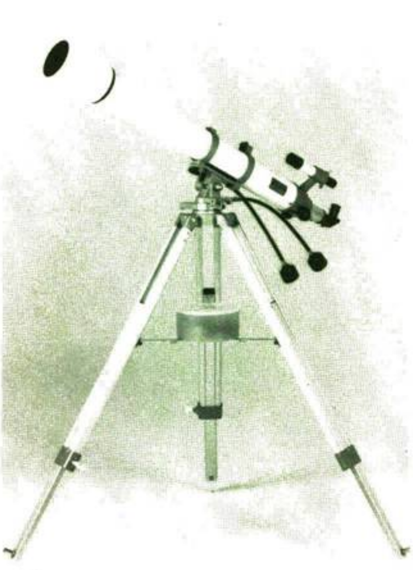

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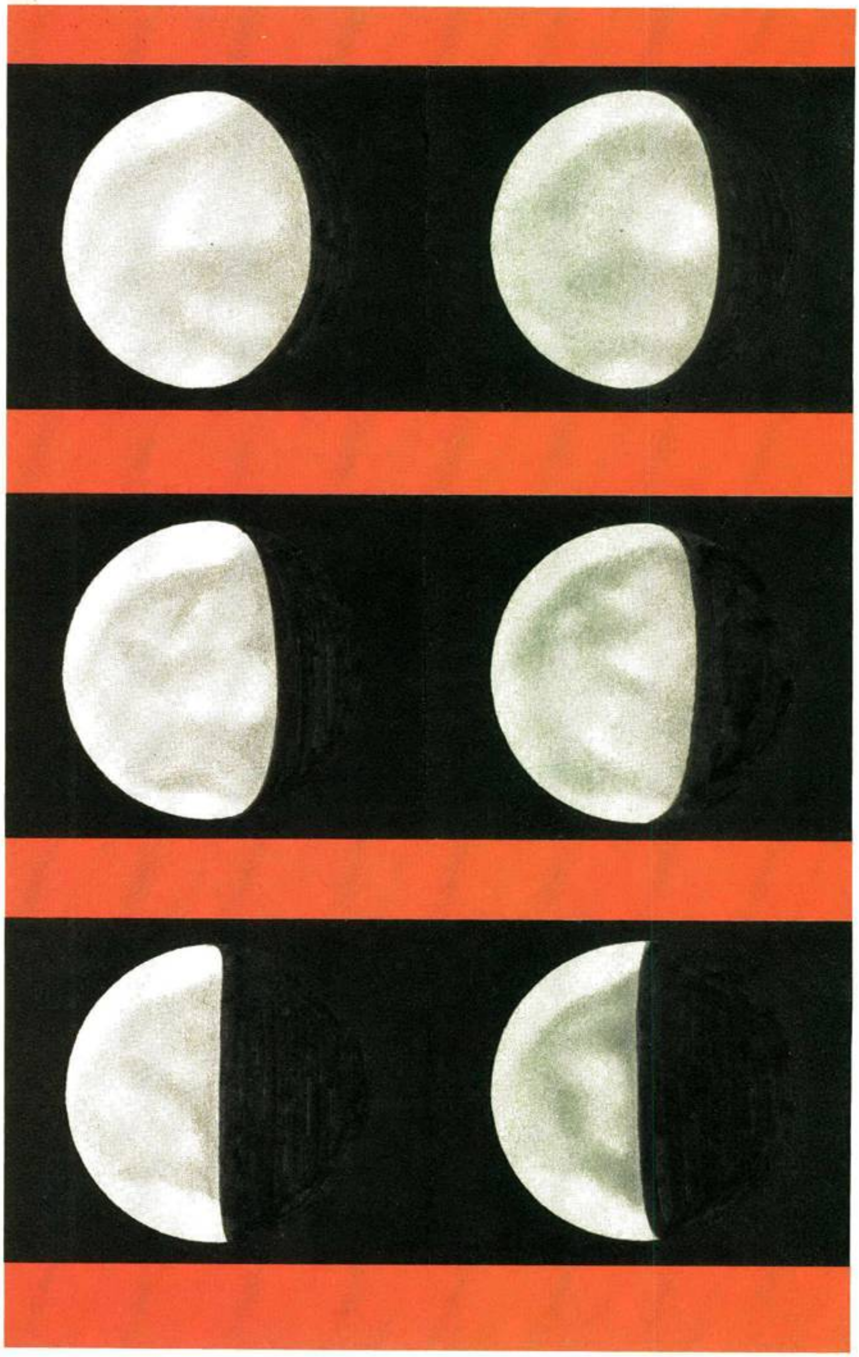
FOLLOWING THE SHADES OF VENUS

Matthew Boulton has been following the shades of Venus for a long time. It's a lonely job in the world of planetary observing, much less flashy than, say, watching the belts and clouds of Jupiter or the changing dark markings on Mars. Nevertheless — perhaps because it requires a precise, patient eye — Boulton and his friend Paul Smith have been making sketches of Venus. Their site is "in the middle of nowhere" in the English midlands (Boulton lives in Redditch, Worcestershire).

"Since February the brilliant white light of Venus has especially drawn our attention," says Boulton. "Last March the planet gained considerable altitude in our sky and we could begin to make worthwhile observations. I have been closely observing Venus for over four years now, and unlike other apparitions I have observed, this has been by far the most interesting for seeing genuine detail in the planet's atmosphere."

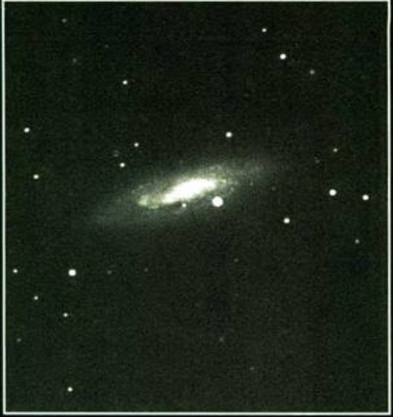
Because the details visible on Venus are of extremely low contrast, Boulton emphasizes the importance of using the correct color filters to maximize visible features. "I have found that a blue filter is an extremely useful all-around filter for Venus, for revealing the bright poles and dusky shadings," he says. "I also now believe that the common advice to view Venus shortly after sunset or before sunrise is misleading. We have found that by far the best time to spot details is in broad daylight, when the planet is close to the meridian. If that is not possible, view Venus an hour or two before sunset, when the sky is still quite bright. The image will be high-quality and shadings on the planet more easily visible."

Atmospheric seeing is crucial for observations of Venus, according to Boulton. "We have observed irregularities along the terminator on several occasions this spring, especially as Venus entered its crescent phase. However, when the seeing isn't particularly good, it's easy to imagine that you see features along the terminator. It's very important to observe when the sky is steady." That's advice applicable not just to watchers of Venus, but all backyard astronomers who care about what they're seeing. — *David J. Eicher*



SHADOWS AND STREAKS in the atmosphere of Venus are visible in these sketches by Matthew Boulton. The sketches were made on March 29, 1991 (top left), April 15 (top right), May 1 (left center), May 7 (right center), June 13 (bottom left), and June 20 (bottom right). All sketches were made with a 6-inch refractor at 213x. The first sketch was made with a yellow filter, the second with a neutral density filter, and the rest with a blue filter.

A SPECTACULAR PLANETARY CONJUNCTION

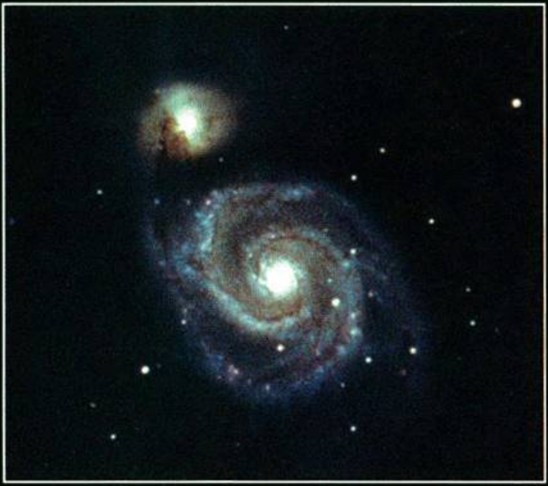


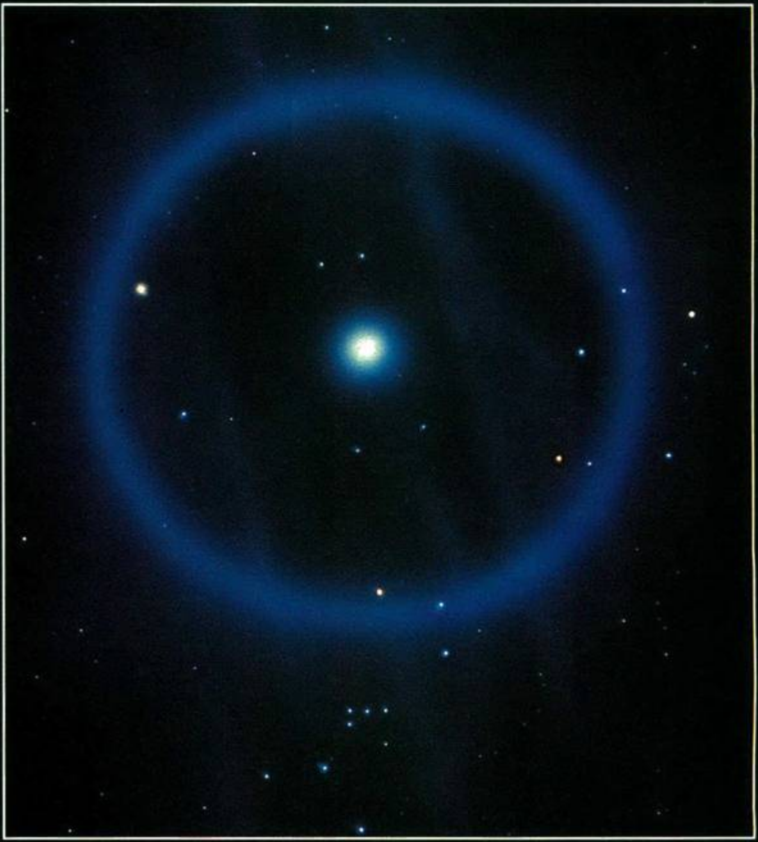
Bright planets Venus, Jupiter, and Mars converged to within a few degrees of each other on June 15, 1991. On that night, the waxing crescent Moon joined the group of planets and created an unforgettable sight. Tulsa, Oklahoma astrophotographer Bill Sterne wins this month's $100 "Best Astrophoto" award for his record of the event (opposite page).

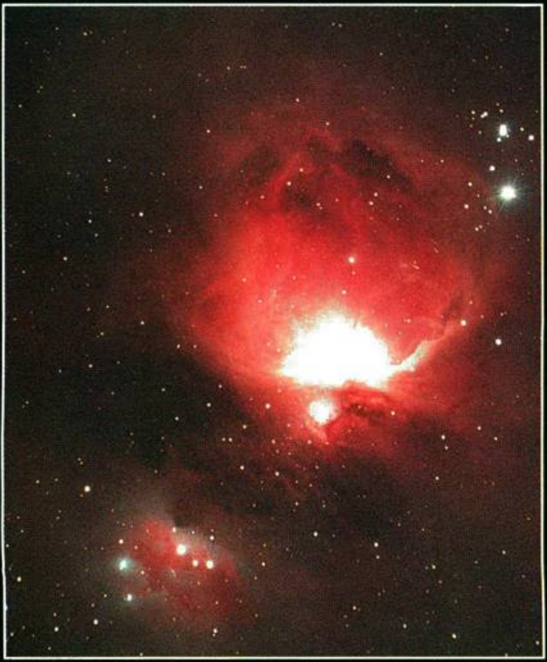
On April 16, amateur astronomer Stephen Knight of Waterford, Maine, spotted a "guest star" lurking in a spiral arm of the galaxy NGC 4527 in Virgo. As many observers began to watch supernova 1991T, as it was designated, it was clear this Type Ib supernova was on the rise. By early May, the object shone at magnitude 11.5, glowing about as bright as a supernova at the distance of the Virgo Cluster can. (NGC 4527 is a member of the Virgo Cluster of galaxies.) On May 5, Tom Dey of Springwater, New York, captured the bright star just off the galaxy's disk (right). Chris Cook's photo of the supernova preceded Dey's by three nights (bottom right).

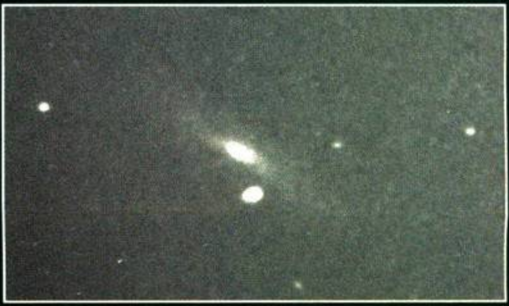
While some were photographing exotic guests in the sky, others recorded stunning images of old favorites. Bill and Sally Fletcher's photo of the Whirlpool Galaxy in Ursa Major (below left) shows knotty structures and dark matter in the bluish spiral arms. Tom Orzechowski's photo of the Orion Nebula (bottom left) shows the great extent of faint, outer nebulosity surrounding the bright, central region.

Observers do not live by deep-sky objects alone, however. Edwin Faughn, an artist at Memphis' Pink Palace Planetarium, rendered this view of a lunar halo he observed on March 23 (below right). Jupiter is visible inside the halo at right, and Mars at lower right. The constellation Orion lies below the Moon's icy glow.









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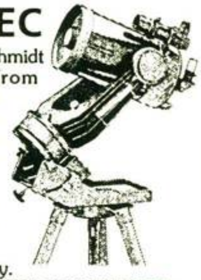
The new Powerstar PEC features Celestron's famed 8 inch Schmidt Cassegrain optics with **Starbright** coatings, PEC periodic error correction DC servo drive system & Byers worm gear for improved tracking accuracy, 30mm Plossl eyepiece, 6x30 finderscope 1X" Star Diagonal, case, wedge & rubberized tripod **$1539**

ULTIMA 8 PEC



The state of the art 8 inch Schmidt Cassegrain telescope from Celestron. It features a rugged swing fork mount with carrying handles for ease of set up, a massive cast polar shaft with 4" ball bearings, 7½" Byer's worm gear drive & PEC periodic error correction drive system for the ultimate in drive accuracy.

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ULTIMA 11 PEC

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- Equatorial Mount w/Tripod
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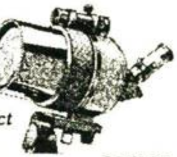

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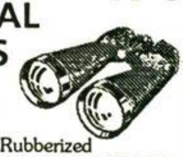

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DOBSON ON DOBSONIANS

How and Why to Make a User-Friendly Sidewalk Telescope, by John L. Dobson, (Everything in the Universe, 1991), ISBN 0-913399-63-9, 154 pages, hardcover [very; see below], $39.95.

Here's John Dobson on how to build a Dobsonian telescope; you just can't get more authoritative than that.

The first three of the book's four chapters take up only a third of the pages. These provide an autobiographical sketch of Dobson (as told to editor and publisher Norm Sperling), recount stories about Dobson's travels with the San Francisco Sidewalk Astronomers club to popularize astronomy, and offer a brief guide to what the universe has to show you. These sections convey a relaxed and philosophical approach to sky gazing.

The last chapter, which makes up most of the book, is a practical and well-illustrated manual on how to grind and test an 8-inch mirror for a Newtonian reflector, construct the telescope tube, and build a Dobsonian mounting for it. The procedures are thoroughly detailed (although Dobson gives relatively few specific dimensions) and cover everything from how to recycle old shingles into spider vanes for the secondary to aligning the optics.

Above all, this is a handbook for *doers.* Dobson wants you to build your own telescope virtually from scratch, preferably with scavenged and discarded materials, and not just bolt together a few premanufactured, relatively expensive elements. The largely homemade approach is unquestionably cheaper, but I also get a strong sense that Dobson feels it's better for your soul to do it that way anyhow. Dobson is a person who left the atom bomb project in 1944 and spent most of the following quarter century in Vedanta monasteries in California. He made a number of telescopes there only because he became highly adept at creatively reusing scrap. But even if the Dobsonian telescope was born from industrial junk out of necessity, it also neatly reflects its originator's philosophical convictions.

I have met certain amateur astronomers — perhaps you have too — who would find Dobson's blend of glass-grinding and mysticism about as enjoyable as a fingernail screech on a blackboard. But I also know sky watchers who would delight in an approach to astronomy and telescope making that puts far more stress on inward reflection about the universe than on doggedly contributing to science.

By the way, this really *is* a "hardbound" book — the covers are made of $^{1}/_{4}$" plywood! Some may think this touch is gimmicky, but I'm delighted; it's marvelously appropriate. — *Robert Burnham*

Observing Guides

Exposure Guides for the Sun, Moon, and Planets, by Ginger LeGendre, (Sky Publishing, 1991), ISBN 0-933346-61-1, 78 pages, paperback, $8.95.

Novice astrophotographers often worry about what exposure to give a celestial object. The variables can seem bewildering: film speed, object brightness, and effective focal ratio (which in itself is a combination of variables). This short book provides tables of sample exposures for most solar system objects, using various f/ratios. Afocal, eyepiece projection, and prime focus methods are also briefly described.

General Astronomy

Lunar Sourcebook, edited by Grant H. Heiken, David T. Vaniman, and Bevan T. French, (Cambridge University Press, 1991), ISBN 0-521-33444-6, 736 pages, hardcover, sewn binding, $59.50.

This work carries the subtitle "a user's guide to the Moon," and that's just what it is. Eleven chapters summarize what has been learned about such topics as lunar minerals, rocks, regolith, chemistry, physical properties, and geologic history. The intended audience is professional planetary scientists, but experienced amateurs will find lots to explore in it.

Challenges of Astronomy, by Wolfhard Schlosser, T. Schmidt-Kaler, E. F. Milone, (Springer-Verlag, 1991), ISBN 0-387-97408-3, 236 pages, acid-free paper, sewn binding, hardcover, $39.00.

In 30 self-guiding projects meant for astronomy labs, the reader is led to explore such topics as atmospheric effects on starlight, planetary surface temperatures, spectral analysis, and the speed of light.

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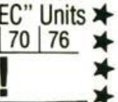

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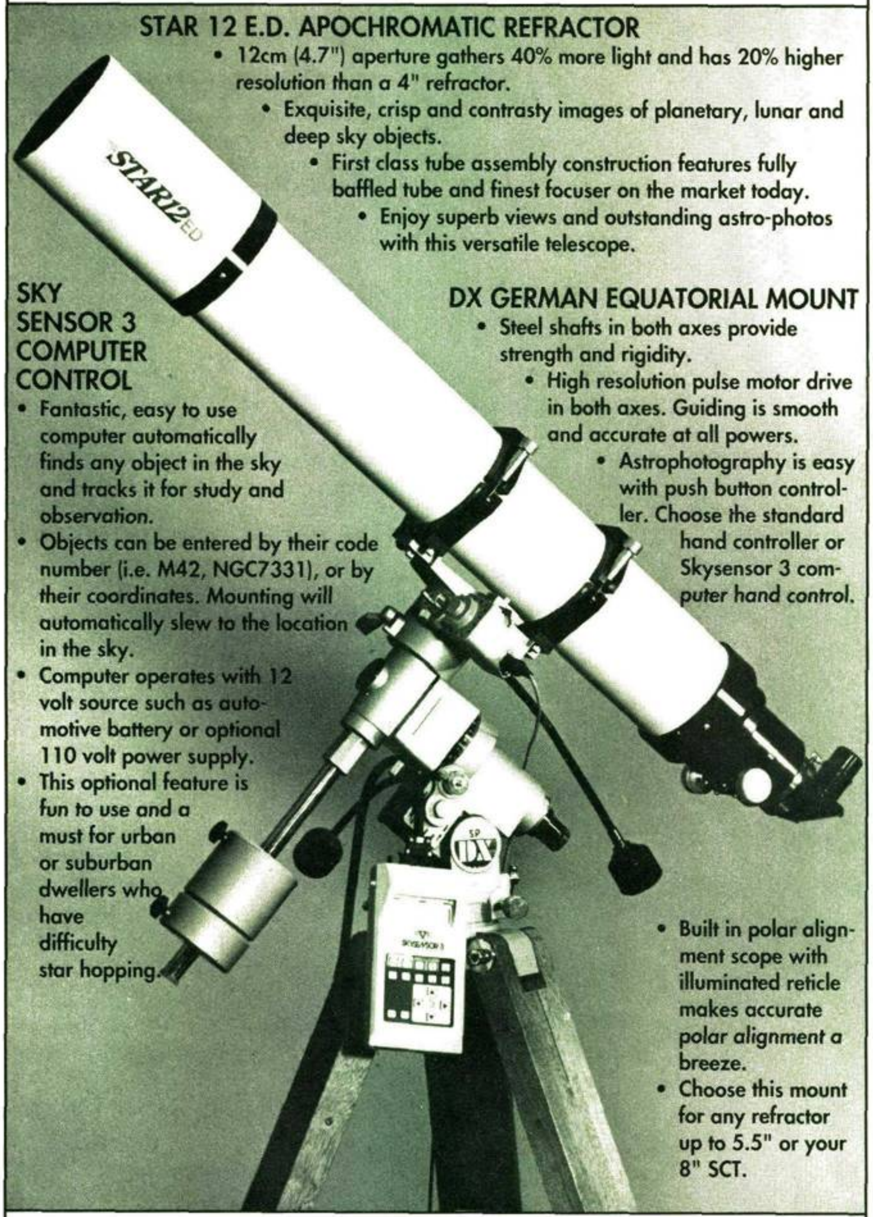

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From the Hill: The Story of Lowell Observatory, by Rose Houk, (Lowell Observatory, 1991), 48 pages, paperback, $9.95. [No ISBN available; order from the observatory, 1400 W. Mars Hill Road, Flagstaff, AZ 86001 and include an extra $1.25 for postage.]

From the Hill is a short but well-written, colorfully illustrated, and beautifully printed book about Lowell Observatory. It covers the observatory's history, its instruments, and the astronomical research done there. The book portrays many of the astronomers who have worked at Lowell in the past, foremost of course being Clyde Tombaugh, who discovered Pluto there in 1930. But the book also offers a good look at the astronomers who work there now and their research. Published as Lowell approaches its centennial (1994), this book makes a handsome snapshot of a great observatory.

Greek Astronomy, by Thomas L. Heath, (Dover Publications, 1991), ISBN 0-486-26620-6, 192 pages, paperback, $6.95.

Although our sky lore contains legacies from older cultures, Western astronomy largely began with the Greeks. This anthology (first published in 1932 and long out of print) presents translations of selected key excerpts from many major and minor Greek philosophers' works on astronomy. The index is short but thorough.

Molonglo Reference Catalogue of Radio Sources, Department of Astrophysics, University of Sydney, 1990, 5 1/4" floppy disk, 1.2 megabytes, IBM format, free.

This is the machine-readable version of an astronomical catalogue published in 1981. It contains 12,141 radio sources located between 18°30' north and 85° south declination (1950.0), as surveyed by the Molonglo Radio Telescope in Australia. (The instrument is a 1 mile by 1 mile cross-shaped interferometer.) The survey was made at 408 MHz and includes all sources stronger than 0.7 jansky. The disk contains the catalog and documentation in ASCII format, plus Fortran software to search the catalog.

The *Reference Catalogue* is available free of charge from the Department of Astrophysics, University of Sydney, New South Wales 2006, Australia. (Users are requested to inform the department of any use they make of the catalog, such as publications or exhibits.) ☐

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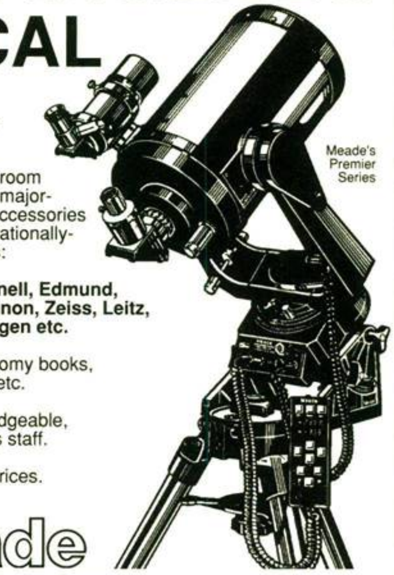

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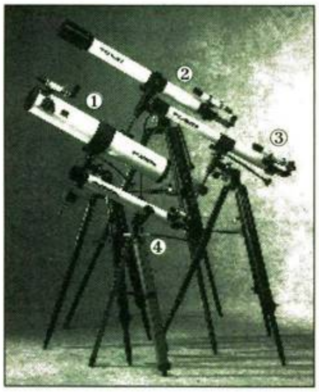

❹ Orion TeleVista 60mm Altazimuth Refractor

This affordable telescope is equally at home viewing the rings of Saturn or boats across the bay. One of our most popular sellers, it will provide you with years of enjoyment viewing celestial and earthly delights. It includes a quality coated 2-element achromatic objective lens and two quality Kellner .965" eyepieces, 25mm & 9mm, for sharp, clear images at 28x and 78x. Sturdy all metal optical tube and yoke mount, plus strong adjustable wooden tripod, smooth focuser and diagonal prism. A great, economical choice for observers of all ages.

#9091 **$199** (8.97)

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America's biggest & best selection of telescopes, binoculars & accessories. Now 3 convenient Northern California locations!

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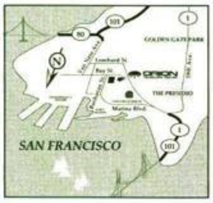

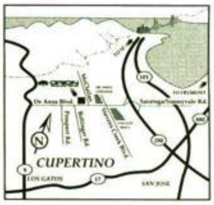

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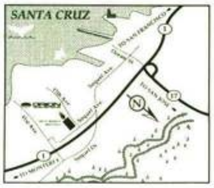

Orion® Big Eye™ 8x50 & 11x80 Finder Scopes

You might spend more time viewing through the finder than through your main telescope! Big Eye Scope is Ideal for upgrading any telescope including Schmidt-Cassegrains. Available non-illuminated or with wireless, adjustable, battery-operated illuminated reticle and Polaris grid for accurate polar alignment. With 90° diagonal prisms. Optional deluxe dual-ring brackets are perfect for 8" and 10" Celestron or Meade; will fit many others, too.

8x50 Models The 50mm objectives gather 2.7 times more light than 30mm finders!

8x50 Standard Finder #7100 **$89.95** (3.95)

8x50 Illuminated Finder #7135 **$129** (4.19)

Bracket— For 50 mm #5143 **$25.95** (2.98)

11x80 Models These huge finders gulp in over 7 times the light of 30mm finders; 2.5 times more than 50mm models!

11x80 Standard Finder#7146 **$199** (4.71)

11x80 Illuminated Finder #7143 **$269** (5.28)

Bracket— For 80 mm #5140 **$37.95** (2.98)

Superior Performance 7x50 Adlerblick Binoculars

Incredible wide field eyepiece design, Fully Multi-Coated, BAK-4 prisms, and best special glass objective lenses make the 7x50 Adlerblick the arch rival of European brand binoculars selling for 3-4 times the price. Orion buys direct, saving you money. Includes deluxe hard case, lens caps and straps.

#9612 **$279** (5.28)

Orion® 10x70 Fully Multi-Coated Enhanced Giant Binoculars

The standard for hand-holdable astronomy binoculars. 33% lighter—weighs only 58 oz.—yet the same brightness and 7mm exit pupil as our 11x80 MC model. Superior 'BCF' body design. Includes: soft rubber eyecaps, tripod mounting adapter, durable hard carrying case, lens caps and straps.

#9501 **$299** (6.97)

Orion® Enhanced® Giant Binoculars

20% more light transmission than ordinary "fully coated" binoculars. Fully Multi-Coated optics and superior BAK-4 prisms provide fantastic contrast and greatly improved edge sharpness.

11x80 MC- Brightest, widest field available. Ideal for deep-space observation under dark skies. Hand-holdable.

#9502 **$369** (8.05)

16x80 MC- 45% higher power, excellent for astronomy and daytime observation. Tripod recommended.

#9496 **$379** (8.05)

20x80 MC- Highest power model perfect for smaller deep-space objects and long range daytime views. Tripod required.

#9498 **$389** (8.05)

Orion® Sky Explorer™ Mini Deep Sky 8x56 Binoculars

56mm objective lenses gather over 2.5x the light of ordinary 7x35 binoculars. Perfect for viewing faint celestial objects, daytime viewing. Best Multi-Coated BAK-4 optics. 6° field of view. Weighs 33 oz.

#9504 **$149** (4.71)

SuperGiant™ 14x100

Gigantic 100mm (almost 4 inch!) lenses gather 156% of the light of 80mm binoculars. Individual eyepiece focus improves alignment and allows for more precise focus. They feature fully multi-coated optics and BAK-4 prisms. Comes with the integral platform tripod mounting plate and metal-clad case. 14x magnification, field of view 3.3°, exit pupil 7.0mm, weight 7.5 lbs., height 13.5".

#9495 **$899** (17.12)

Orion® 7x50 Observer™ Binoculars

Our new Observer binocular is an ideal moderately priced night vision binocular for both astronomy and general purpose daytime observation. Fully coated optics with a 7° field of view, and a bright 7mm exit pupil. Rugged ribbed rubber covering for a good grip.

#9620 **$84.95** (4.44)

Orion® 12.5mm Plössl Illuminated Reticle Eyepiece

This new 12.5mm 4-element Plössl offers unprecedented eye relief and observing comfort during long astrophoto exposures. The battery operated integral illuminator has fully adjustable brightness. Features double crossline reticle.

#8484 **$99** (3.45)

World's Finest Illuminated Reticle Eyepiece

6mm Orthoscopic design for required high power guiding, plus unique X-Y adjustable reticle positioning for easy guide star alignment. Wireless LED illuminator has adjustable brightness.

#8487 **$149** (3.67)

Orion® 9mm Orthoscopic Illuminated Reticle Eyepiece

9mm Orthoscopic eyepiece with wireless adjustable brightness illuminator. Bull's-eye within three concentric circles helps measure limits of acceptable guiding error.

#8488 **$119** (3.67)

Orion® 12mm Kellner Illuminated Reticle Eyepiece

12mm Kellner eyepiece with cable plugs into LX/3, LX/5 and Premier drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding.

#8482 **$69.95** (3.45)

Orion® 2" Barlow Lens

2x magnification, Multi-Coated, 2-element 40mm diameter achromatic lens. Baffled to eliminate off-axis glare. Works with all 2" barrel diameter eyepieces. Chrome plated brass barrel and blackened aluminum body with knurled set screw.

#8720 **$79.95** (3.95)

Orion® VariPower™ 2-3x Multi-Coated Barlow Lens

Our best barlow fills the gaps in your eyepiece collection. Internal lens cell slides easily to adjust magnification. Quality optics provide excellent sharpness, contrast and brightness. Works with 1.25" diameter eyepieces and right-angle diagonals.

#8748 **$69.95** (3.45)

Orion® 3-Element Fully Multi-Coated Barlow Lens

Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter.

#8750 **$64.95** (3.45)

Orion® Deluxe Fully-Baffled Multi-Coated Barlow Lens

Fully internally opaqued and baffled to block stray light for noticeably higher contrast. Large 27mm multi-coated 2-element lens provides 2x magnification with any 1.25" eyepiece.

#8746 **$49.95** (2.98)

StereoScope™ Binocular Viewing Expander

Open up a new dimension in observation! The stereo effect of this viewer is astonishing. Viewing is more comfortable and it shows more detail, especially of the Moon and planets. Specially built for astronomical telescopes, features a fully adjustable 55-75mm interpupillary distance scale and a highly precise beam splitter which maximizes transmission of light to each eyepiece and equalizes the brightness of each image. Threads securely onto any Celestron or Meade Schmidt-Cassegrain. Includes a thread-on matched 2x Barlow lens. (Shown with two eyepieces, not included.)

#9720 **$429** (6.13)

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77° Field UltraScan Wide Angle Eyepieces

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1.25" UltraScan Eyepieces
Five optical elements utilizing the latest high refractive-index optical glass materials achieve extremely wide fields with fewer elements than many competitive eyepieces, reducing weight and cost. Each lens surface is Fully Multi-Coated, for the ultimate in contrast and elimination of stray reflections. Integral rubber eyeguards.

9mm-#8420 **$99** (3.45), *12mm*-#8421 **$109** (3.67)
15mm-#8422 **$129** (3.67), *19mm*-#8423 **$139** (3.67)

2" UltraScan Eyepieces
These incredible oculars provide breathtaking panoramic, bright views that will astonish you!

30mm 2" UltraScan Eyepiece–This 5-element, 77 degree field UltraScan eyepiece combines the widest possible apparent and true fields with a larger image scale than our 40mm.
#8424 **$219** (4.71)

40mm 2" UltraScan Eyepiece - Orion's brightest, widest true-field UltraScan eyepiece utilizes a sophisticated 7-element design, providing a 68 degree apparent field, the widest we could fit into the 2" diameter barrel.
#8425 **$199** (4.19)

High Resolution Orion® Ultrascopic Eyepieces

Unlike other premium eyepieces, Orion Ultrascopics offer complete multi-layer coatings on ALL surfaces, for superior light transmission and contrast. Modern 5- and 7- element designs for pinpoint star images and breathtaking detail. Wide 52° field of view. Compare with other brands selling for much more!

Wide Field 5-element
35mm #8560 **$99.95** (3.45)
30mm #8562 **$89.95** (3.45)
25mm #8564 **$74.95** (3.45)

Medium-High Power 5-element
20mm #8566, 15mm #8568, 10mm #8570, 7.5mm #8572
$69.95 ea. (3.45)

High Power 7-element 5mm #8574, 3.8mm #8576
$89.95 ea. (3.45)

Orion® MegaVista™ 1.25" Wide Angle Eyepieces

Incredible Fully Multi-Coated high-transmission 7-element eyepieces with integral rubber eyeguard and long eye relief.

10.5mm—An incredible 67° field for outstanding planetary or deep space performance.
#8552 **$119** (3.67)

16.8mm—Outstanding high-contrast eyepiece with stunning 70° field ideal for deep space.
#8554 **$119** (3.67)

Orion® UltraZoom™ 7-21mm 1.25" Eyepiece

The finest zoom you can buy for your 1.25" telescope. An excellent choice for astronomy or terrestrial observing. 65°-35° field.
#8556 **$139** (3.67)

Orion® Explorer Series 1.25" Eyepieces

Remarkably affordable, Multi-Coated parfocal eyepieces with great performance. Each carefully selected series has been chosen to provide a sensible progression of magnifications. Threaded for filters. Internally blackened to prevent stray light reflections.

Kellner Eyepieces-
6mm #8536, 9mm #8538, 12mm #8540, 18mm #8508, 25mm #8510, 40mm #8512
$38.95 ea. (2.98)

Orthoscopic Eyepieces-5mm #8500, 7mm #8502, 9mm #8504, 12.5mm #8506, 18mm #8524, 25mm #8526
$49.95 ea. (2.98)

Orion® Explorer Series .965" Eyepieces

Get the most from your small telescope with these fine Multi-Coated eyepieces. Standard .965" barrels fit all Japanese standard small telescopes.

.965" Orthoscopic Eyepieces-
5mm #8580, 7mm #8581
9mm #8582, 12.5mm #8583
$46.95 ea. (2.98)

.965" Kellner Eyepieces
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Orion® SkyGlow™ Enhanced Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters-Photographic and Visual
For use in slight to moderately light polluted areas.

1.25" Broadband Filter–fits 1.25" eyepieces.
#5660 **$69.95** (3.45)

Schmidt-Cassegrain Broadband Filter–fits rear cell of Meade & Celestron SC scopes.
#5658 **$89.95** (3.45)

52mm Broadband Filter–For 52mm camera lenses, adapter rings available for other diameters.
#5668 **$89.95** (3.45)

SkyGlow UltraBlock Filters-Visual Only
For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter–fits 1.25" eyepieces.
#5654 **$99.50** (3.45)

Schmidt-Cassegrain UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes.
#5656 **$139** (3.67)

Orion® Color Filters for Eyepieces

Solar system observations are dramatically improved by Orion colored filters. For visual use, thread one into the barrel of any standard eyepiece. For planetary and lunar photography, Schmidt-Cassegrain owners can attach the filter to the eyepiece inside the tele-extender. Can also be threaded directly into a universal camera adapter.

Basic Set of 4 Filters .965"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.
#5510 **$34.95** (2.98)

Basic Set of 4 Filters 1.25"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.
#5514 **$44.95** (2.98)

Expansion Set of 4 Filters 1.25"- Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.
#5516 **$44.95** (2.98)

Deluxe Set of 8 Filters 1.25"- Includes all the filters in our basic and expansion filter sets.
#5517 **$84.95** (3.45)

Individual 1.25" Filters- #80A Blue (#11040), #58 Green (#5540), #25 Red (#5536), #15 Yellow (#5532), #21 Orange (#5534), #47 Violet (#5538), #11 Light Yellow-Green (#5530), #82A Very Pale Blue (#5544)
$13.95 ea. (2.43)

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.
.965" #5664 **$14.95** (2.43)
1.25" #5662 **$14.95** (2.43)

Breakthrough Low Price Plössl Eyepieces!

These new Multi-Coated Plössl eyepieces are incredibly low priced! Good quality optics for sharp, clear images. Precision 4-element Plössl lens elements mounted in sturdy aluminum barrels. Available in 12mm, 18mm, or 25mm focal lengths, with 1.25" barrels. Buy all three for less than some single eyepieces!

12mm-#8596
18mm-#8597
25mm-#8598 **$44.95 ea.** (2.98)

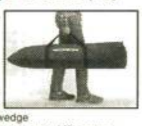
Deluxe Eyepiece Case

Organize and protect your valuable eyepieces and other accessories. This durable case with double hinges holds up to 10 eyepieces plus barlow. Die cut foam insert for snug secure fit. O.D. 8-1/2"x12-1/2"x3-1/8".
#5913 **$17.95** (2.78)

Deluxe Metal-Clad Accessory Cases

Keep accessories and camera safe and clean. Diced foam inserts can be tailored to your needs. Sturdy handle, two latches, key.
Regular Case: 16"x12"x61/2" #5920 **$59.95** (6.67)
Large Case: 191/2"x12"x61/2" #5921 **$69.95** (7.10)

Deluxe Field Tripod Tote Bag



Designed for the field tripod with padded insert to separate wedge from tripod during transportation. Specifically made for wedge combinations of Schmidt-Cassegrain telescopes up to 10" aperture. Allows storage without changing polar alignment. This blue bag is made of tear, rip and mildew resistant 100% Cordura nylon.
#15096 **$79.95** (5.19)

Orion® FlexiShield™ Dew Caps

Eliminate dew problems with FlexiShield! Better performance, more rugged, and easier storage than rigid dew caps. Forms into a tube with the velcro closure, opens flat for easy storage and transportation. Fits your telescope tube snugly, with wide rubber padding and full length velcro closure—needs no screws. Models to fit most telescopes.

90mm Celestron/Meade Spotting Scopes	#4203	**$24.95**	(2.78)
90mm Celestron Rubber Armored Spotting Scopes	#4205	**$24.95**	(2.78)
4" Meade Schmidt-Cassegrain	#4204	**$24.95**	(2.78)
8" Celestron/Meade Schmidt-Cassegrains	#4200	**$39.95**	(2.98)
10" Meade Schmidt-Cassegrains	#4201	**$49.95**	(2.98)
11" Celestron Schmidt-Cassegrains	#4202	**$59.95**	(3.95)

Orion® Dew Zapper

Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.

8" Dew Zappers-fit all Meade & Celestron 8" Schmidt-Cassegrains
DC Model #3503, AC Model #3504 **$44.95** (2.98)

10" Dew Zappers- fit all Meade 10" Schmidt-Cassegrains
DC Model #3506, AC Model #3508 **$44.95** (2.98)

Dew Remover Gun

Moisture that interferes with viewing dissipates quickly with this 12V DC, 156 watt warm air gun. Has 4-1/2' cord.
#5601 **$17.95** (2.78)

Orion® Slow Motion Adapter

Attaches to your tripod pan head and gives you two slow motion control knobs to make precision adjustments in altitude and altazimuth. Very handy for tracking planets, the Moon, etc. with refractor telescopes and small spotting scopes. Attaches to any camera tripod with a standard 1/4-20 thread.
#7012 **$49.95** (2.98)

Orion® Dual Balance System

Unlike ordinary counterweights, our system allows instant adjustment in both directions. Easily balances your scope to offset both piggyback loads or rear cell cameras, 2" diagonals, and other accessories. Rigid, precision machined dovetail bar mounts to telescope in existing accessory holes.

For Meade SC 8"	#5150	**$74.95**	(4.78)
For Celestron 8" C-8	#5149	**$79.95**	(4.78)
For Meade SC 10"	#5152	**$84.95**	(4.78)

Starlite Red LED Flashlight

The Starlite is the only adjustable-brightness night-vision red flashlight. Lifetime solid-state LED can't burn out. Extra efficient electronic circuit for long battery life. Uses one 9-volt battery (not included).
#5714 **$24.95** (2.43)

Astronomer's Flashlight

Indispensable and indestructible. Has special night-vision red filter and a diffusion lens for even illumination. An essential addition to your astronomy accessories. Requires 2 D-cell batteries (not included).
#5701 **$9.95** (1.79)

Rechargeable Battery Porta Pac

12 Amp Hour Porta Pac
Ideal for operating your telescope plus higher power-consuming accessories such as an Orion Dew Zapper Battery is encased in high impact polystyrene. Carrying case of Cordura nylon with shoulder strap and handle. Wt. 10 lbs.
#2354 **$109 ea.** (8.45)

Popular Observer's Chairs

Make observing more comfortable and enjoyable with one of these great chairs.

Standard Model—
Has adjustable height center column and padded vinyl seat. Folds for easy storage.
#5935 **$39.95** (4.70)

Deluxe Model—
Is much heavier-duty, built for professional musicians. Extra thick padding, wide footprint. Adjustable and disassembles for storage.
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Orion® UltraGuider™

Advanced features most requested by advanced deep space astro-photographers at a low price. Use with your Meade or Celestron Schmidt-Cassegrain telescope. Easily adjustable prism allows wider choice of guide stars. Ultra-precise helical focus of your eyepiece, adjustable camera focal plane position
#5139 **$119** (4.19)

Orion® Premium Off-Axis Guider

Multi-Coated for Peak Performance! Low Orion price for our popular, precision anodized guider.
#5144 **$59.95** (3.45)

Rack & Pinion Focusers

These top quality focusers are designed for Newtonian reflectors. Fit any size tubes.

1.25" Focuser
Quality diagonal-cut rack for smooth focusing. Secure slide-fit eyepiece holder. Integral socket for single-stalk diagonal support if desired.
#13017 **$44.95** (2.98)

2" & 1.25" Focuser
Large clear diameter ideal for larger scopes and wide field optics. Precision diagonal cut rack. Long travel for visual and photographic use. Interchangeable 2" and 1.25" holders with set screws.
#13019 **$74.95** (3.95)

Orion® 45-Degree Erect Image Diagonals

See the world as it really is with Orion's new 45-degree erect image diagonal. Upside-down, backwards and topsy-turvy images can often confuse even the stoutest and most experienced observer. Turn it right-side-up with your choice of three models to select from.

.965 Diagonal	#8759	**$59.95**	(3.45)
1-1/4" Diagonal	#8753	**$59.95**	(3.45)
Size-Adapting Hybrid Diagonal	#8755	**$59.95**	(3.45)

Star Diagonals

1.25" Star Diagonal
Primarily for astronomical use, lets you view at a right angle. Multi-Coated, for 1.25" eyepieces.
#8763 **$39.95** (2.98)

.965" Star Diagonal
Same as 1.25" Star Diagonal, but with standard coated optics. Works with .965" eyepieces and eyepiece holders.
#8761 **$24.95** (2.98)

2" Star Diagonal

Get the widest possible field of view from your Schmidt-Cassegrain Telescope. This star diagonal features a special aluminized and overcoated precision first-surface flat mirror.
#8767 **$99.95** (3.45)

Orion® Tele-Extenders

For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

Standard Tele-Extender
Use this Tele-Extender in conjunction with an eyepiece. Attaches to visual back of Meade or Celestron Schmidt-Cassegrain telescopes, and to 35mm camera with T-ring, sold separately.
#5125 **$27.95** (2.98)

Variable Tele-Extender
Uses an adjustable extension tube, allowing magnification to be changed without switching eyepieces. Attaches with T-ring, sold separately.
#5127 **$39.95** (2.98)

Universal Camera Adapters

Standard Universal Camera Adapters
Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately) to match your 35mm camera.

.965" #5268 **$29.95** (2.98)
1.25" #5264 **$34.95** (2.98)

Variable Power Camera Adapter

Unique sliding barrel design allows variable projection distances during eyepiece projection photography, eliminating the need to change eyepieces when magnification changes are required.
#5262 **$44.95** (2.98)

Orion® T-Adapter

For prime focus photography. Use with T-ring to match your 35mm camera. For Meade, Celestron 4", 8", 10", 11", 14" SC. Can be used as 2" camera adapter.
#5116 **$27.95** (2.98)

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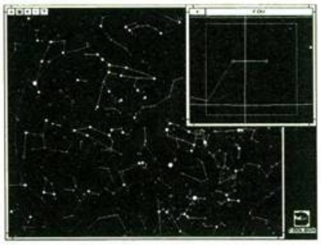

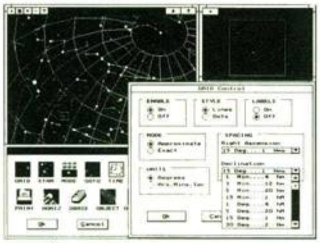

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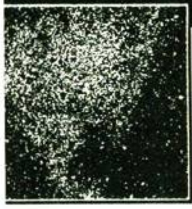
Genesis: Chapter 2



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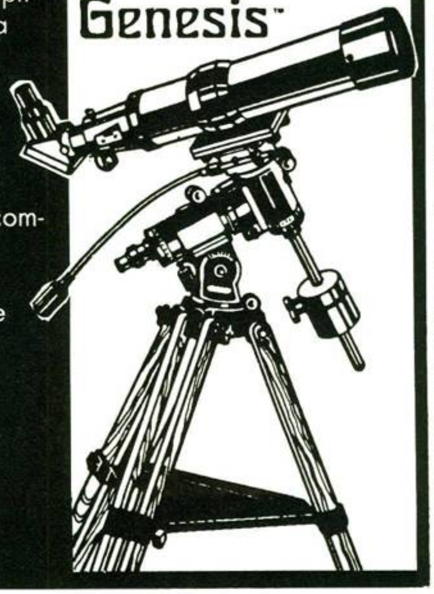

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If you are a fan of comets and want lots of information *fast* on the latest discoveries, *The Shallow Sky Bulletin* (SSB) is the place to look. The *SSB* provides timely, accurate information on all current comets within range of amateur-sized telescopes. The $15 subscription price will bring you six issues (one year) of the *SSB* newsletter as well as *Comet Rapid Announcement Service (CRAS) Notices,* which are published whenever a comet with a visual magnitude 11 or brighter is discovered.

The Shallow Sky Bulletin is edited and published by Cleveland amateur Stephen Smith. This is not a slick publication — it is designed to supply plenty of details in the smallest package. For example, the *SSB* is typeset using a dot-matrix printer with 133 characters per line.

The *SSB* is broken down into a number of useful sections. "Comet Discoveries and Recoveries" reports on all new comets. Each entry includes who discovered the comet and with what instrument, as well as magnitude, date discovered, and basic orbital information like inclination and the size of the orbit. The "Comet News Notes" section provides tidbits of news regarding recent comet observations such as those made of Comet Halley during its latest outburst. "Other Noteworthy Items" contains a grab-bag of facts, from news about organizations and comet hunters to tips such as how the packaging material of red Bic pens can provide an emergency red filter for a flashlight.

However, it is the comet information sheets that are the heart of the *SSB*. Here, each comet is allotted two full pages. The first page is the ephemeris, or a listing of the comet's position in the sky. The *SSB* lists positions for every comet for each day, making it easier to locate a comet without having to interpolate between earlier and later dates. The ephemeris includes the date, right ascension and declination (in both epoch 1950 and 2000), the distance of the comet from Earth and the Sun in astronomical units, the angular distance

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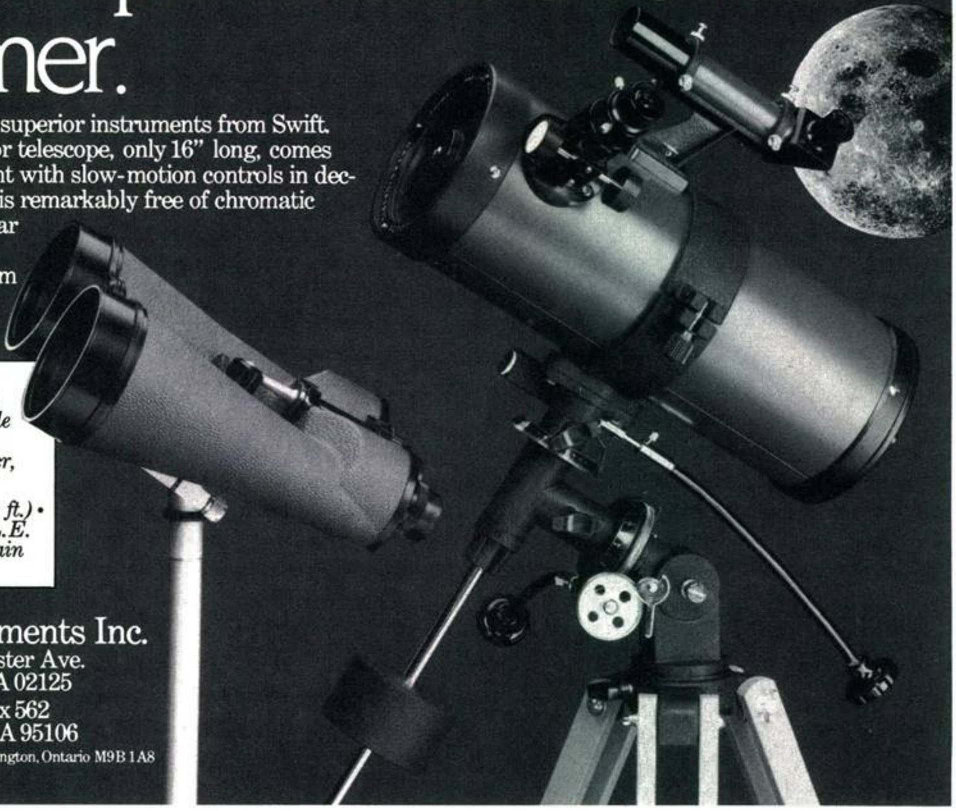

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of the comet from the Sun, its estimated visual magnitude, and the best latitude on Earth from which to see the comet. For astrophotographers with crystal drive controls, the *SSB* also provides recommendations on the best setting for your clock drive so it will track the comet at the proper rate.

The second page is a star chart showing the path of the comet against the stars and the direction that the comet's tail, if present, will be pointed. A feature I like is that even though *SSB* charts often show stars down to a visual magnitude of 9.5, the basic shapes of the constellations are always drawn in, often allowing the observer to orient the chart against the sky without the aid of other charts.

For those with big telescopes, Smith also offers a supplement (appropriately called *Supplement to SSB*) for an additional $15 per year (higher outside the United States). The supplement provides positions and charts of all comets brighter than 15th magnitude and has projected positions and charts for as-yet unrecovered comets.

A great bonus to an *SSB* subscription is the *CRAS Notices.* These are sent to subscribers each time a bright comet is discovered. To do this, Smith regularly monitors the *International Astronomical Union Circulars.* For those that can't get enough information about comets, I can recommend the *Notices* and the *Shallow Sky Bulletin* as good sources of late-breaking information on the newest cometary visitors. — *Robert Bunge*

SOFTWARE UPDATES

The Arizona Database, Version 7.0, *The Arizona Database Project, Inc., 3135 S. 48th Street, Suite #3, Tempe, AZ 85282. $89.95 (includes AZVUE 3.0 database manager). Upgrade for Version 6.0 owners is free. Requires IBM or compatible.*

As I reported in the March 1991 issue of ASTRONOMY, Bob Erdmann and George de Lange have spent the past four years creating and polishing the Arizona Database. Version 7.0, released this past May, contains information on 43,231 deep-sky objects (compared to Version 6's 23,000 entries) that the authors painstakingly gathered from a large number of astronomical catalogs and obscure sources. A great deal of effort has been made to provide the most accurate information available. For example, the authors have identified between 700 and 800 IC objects that some other investigators had failed to fully document. In addition to lots of data, the new version also tells you where you can find descriptions for each object in the observing handbooks by Burnham, Lorenzin, and Luginbuhl and Skiff.

The authors have taken special care to make navigating around the database as easy as possible. The deep sky objects are stored in order of right ascension, and as you move forward in the database, the R.A. of the deep sky objects also increases. Version 7 also makes use of pull-down menus that you can scroll through using the up- and down-arrow keys.

One of The Arizona Database's most useful capabilities is searching a user-defined area of the sky for specific kinds of objects from one or more catalogs. You can restrict the search by magnitude limits and object type by selecting appropriate filters. The filters can be selected from either the main database viewing window or from any one of three multi-object search windows: Area of Sky Search, Search by Constellation, and Search by Uranometria 2000.0 Chart Number.

You can now also search for individual objects by common name as well as by catalog designation. For deep sky objects which appear in more than one catalog, the Arizona Database places the best known designation in the "Object" field. The other designations are stored in the "AKA," or "also known as," field. An object search examines both the Object and AKA fields, allowing you call up an object even when you do not know its most common catalog designation. If you use the Database at your telescope at night, you'll also appreciate the new red-on-black display for those with color monitors.

Once a multi-object search has been completed, the results of that search can be printed out as an observing list in one of several formats. The original Basic option prints out position, magnitude, type, constellation, and *Uranometria 2000.0* and *Sky Atlas 2000.0* chart numbers. Version 7 has added an "Expanded" printout that lists all the catalog data about the object. The "Complete" list adds the personal observing notes you are now able to type into each object's file.

The Arizona Database is the most complete single source of deep sky data which I am aware of. If you have an IBM PC (or a clone) and seven and a half megabytes of available hard disk space, the new and improved Arizona Database can become one of your most valuable observing tools. — *Tom Mote*

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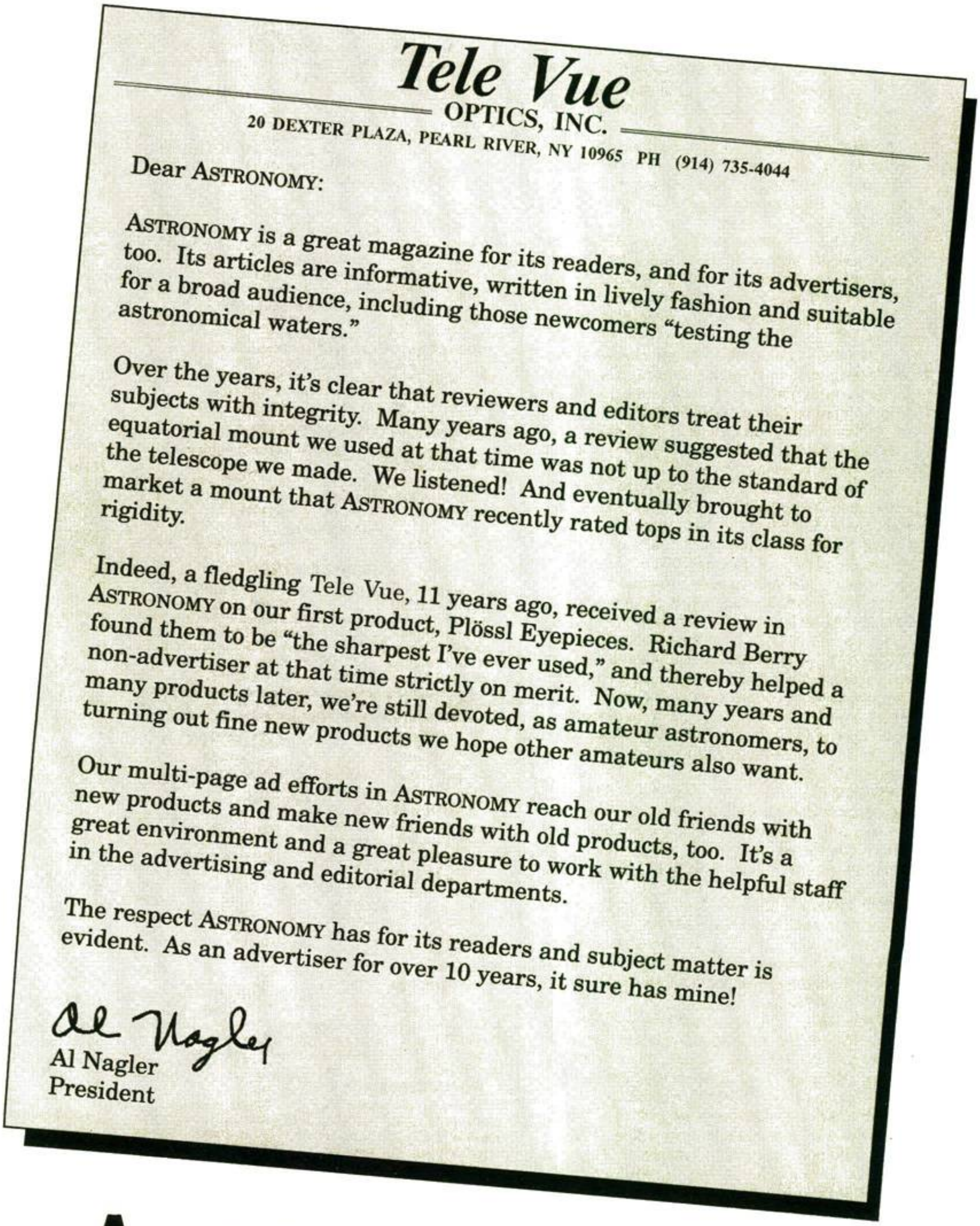

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WANTED — Twenty-one-year-old man would like correspondence from anyone all over the world, especially those who enjoy discussing astronomy, particle physics, cosmology, and atheism. Contact Poh-Meng Liow, Blk 58 Chai Chee Drive, #10-126 Singapore 1646, Republic of Singapore.

FOR SALE — ASTRONOMY Magazine. August 1973 to present. Excellent condition. Best offer. Contact K. Jones, P.O. Box 364, Knob Noster, MO 65336.

ANNOUNCEMENT — The Bucks-Mont Astronomical Association meets the first Wednesday of each month at Peace Valley Nature Center, Chapman Road, Doylestown, PA. Contact Ed Radomski (215) 822-8312.

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FOR SALE — Three .965" eyepieces: 18mm Kellner, 9mm and 6mm Orthos, $25 each. Also .965" Barlow, $20, and .965" Lumicon Deep-Sky Filter, $40. Prefer to sell all for $100. All are used, good condition. Contact Dean in Astoria, NY (718) 726-8835.

FOR SALE — Cheshire Dual-80 refractor telescope, 2 eyepieces with tripod. Unique design 1 short 3" refractor on top of 1 long 3" refractor by one of most prestigious brands. $1,000. Contact Andre Hassid, 927 Augusta, Moraga, CA 94556 (415) 627-5645.

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Jupiter Telescope Company, 810 Saturn Street, Suite 16, Jupiter, FL 33477. $1,395.

2 Radial Guider

Designed for use in prime focus deep-sky photography, Celestron's Radial Guider allows for simultaneous photography and guiding through the main optics of a Schmidt-Cassegrain telescope. Compared to previous Celestron off-axis guiders, the new Radial Guider allows the user to rotate the guiding eyepiece independently of the camera and to move the pick-off prism into or out of the light path to aid in selecting a guide star. The short body length is also claimed to be a better match for the optical characteristics of Celestron's f/6.3 Reducer/Corrector.

Celestron International, 2835 Columbia Street, Torrance, CA 90503, (213) 328-9560. $170.

3

Lightweight Binoculars

Swift Instruments has introduced several lightweight binoculars. The Ultra Lite series includes 7x42, 8x42, and 10x42 models. All weigh 20 to 22 ounces and feature BAK-4 prisms and multi-coating on all air-to-glass surfaces. All are covered in smooth, non-slip rubber. The 7x42 also features extended eye relief for eyeglass wearers while the 10x42 is a wide-angle model.

Swift Instruments, 952 Dorchester Ave., Boston, MA 01215, (617) 436-2960. 7x42: $335, 8x42: $345, 10x42: $365.

This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.

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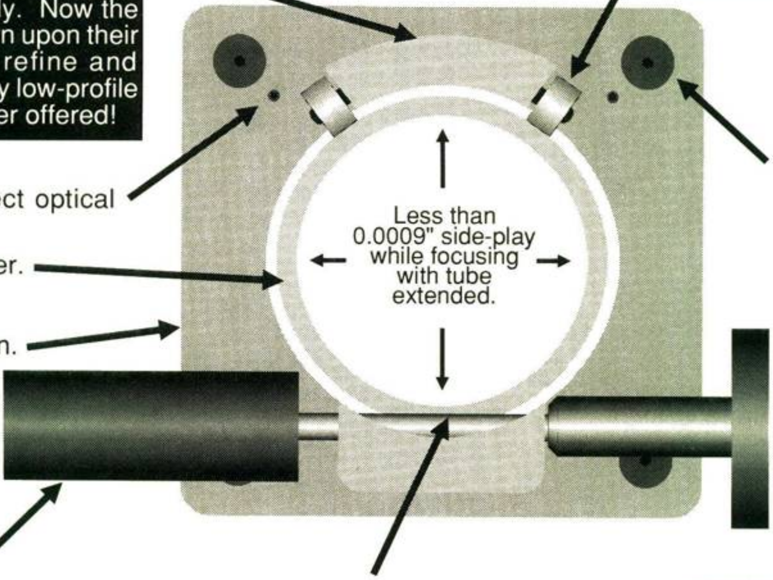

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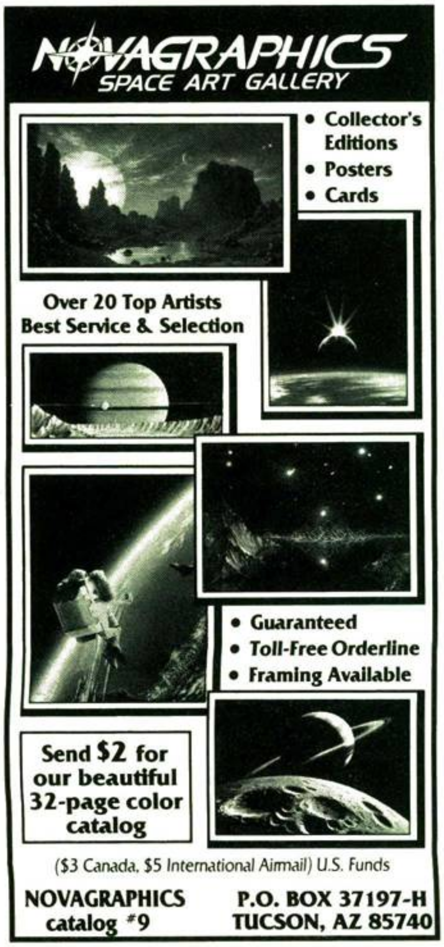

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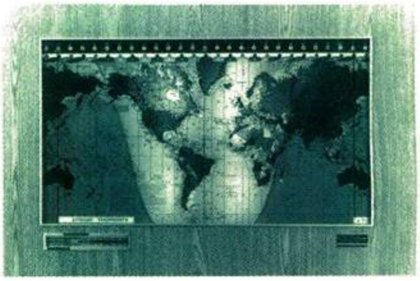
4 Moon and Celestial Globes

Several new globes are available from the Black Forest Observatory. The Moon Globe is 12 inches in diameter and shows the first Apollo landing site. The 12-inch Celestial Globe (shown above) plots 1,200 stars down to 4th magnitude and shows constellations labeled with English and Latin names. The 12-inch Zodiac Globe shows constellations and deep-sky objects when the internal light is off and 70 mythical figures when the globe light is turned on.

Black Forest Observatory, 12815 Porcupine Lane, Colorado Springs, CO 80908, (719) 495-3828. Moon Globe: $39.95. Celestial Globe: $39.95, Zodiac Globe: $89.95. Add $5 per globe for shipping in continental United States (call for Alaska, Hawaii, Canada, and foreign shipping charges).



5 Geochron Clock

The Geochron display is a Mercator projection map illuminated to show the areas of the world currently in sunlight and in darkness. The map scrolls left to right at a speed of one inch per hour. The 3- by 2-foot Geochron also depicts the seasonal shift in the number of daylight hours at each latitude, as well as current time, day of the week, and month in each time zone.

Geochron Enterprises, Inc., 899 Arguello Street, Redwood City, CA 94063, (800) 342-1661, FAX: (415) 361-1780. $1,295.

6 Astronomy Home and School Study Course

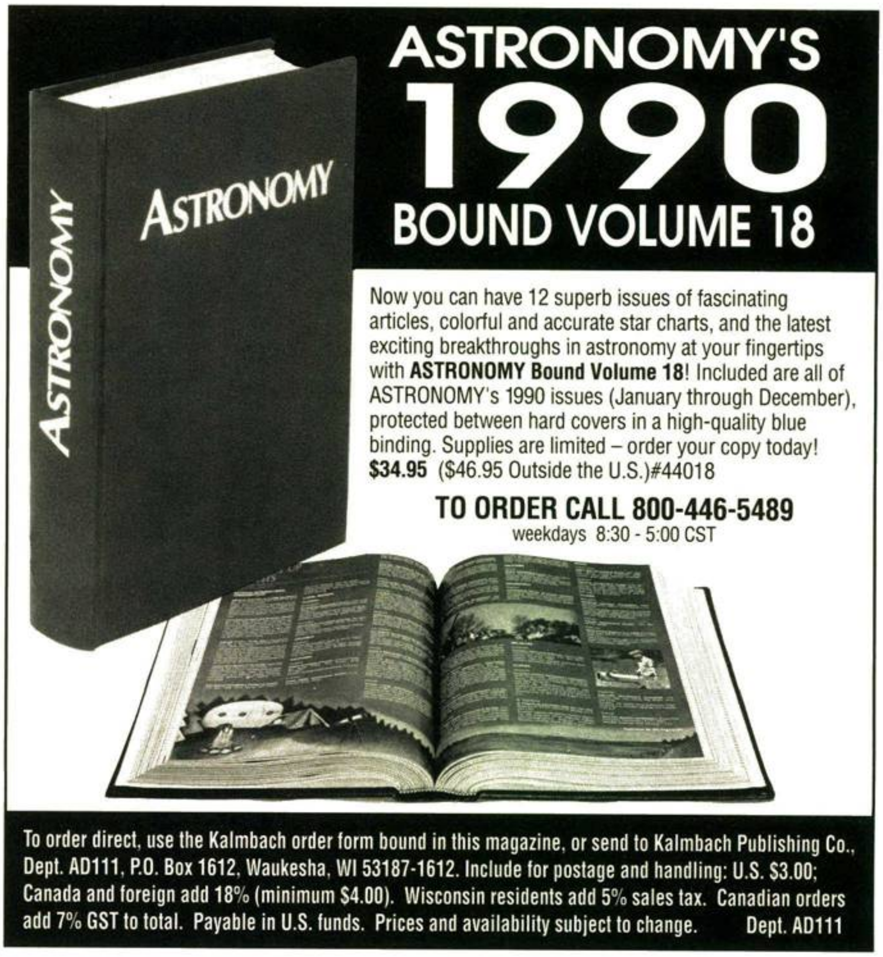
"The Universe" is a home study course on astronomy designed for science teachers of grades 6 to 9. The package contains 13 audio cassettes and a 174-page Teacher Fact Manual. Also included are materials for use in presenting astronomy in the classroom: 6 videos (including 3 MTV-style "rap" videos), 70 color viewgraphs, 3 software diskettes, and information on 50 hands-on student activities.

Education Enrichment Partnership, 2130-A Newbury Road, #420, Newbury Park, CA 91320, (805) 498-9704. $575 plus $15 shipping and handling. Site license agreements available.

7 Focal Tester

Celestron's new Multi-Function Focal Tester (MFFT) is a focusing aid that allows astrophotographers to accurately evaluate their telescope's focal plane image in three ways: focus, collimation, and curvature of field. The MFFT has a black anodized tube and a glass plate with opaque and reflective coatings etched with a special reticle. The tube is machined to place the glass plate at the same distance from the front face of a T-ring as a camera film plane. The MFFT will work with the Celestron Coma Corrector (for Newtonians), and on all Celestron off-axis guiders, T-adapters, and tele-extenders.

Celestron International, 2835 Columbia Street, Torrance, CA 90503, (213) 328-9560. $238. ☐



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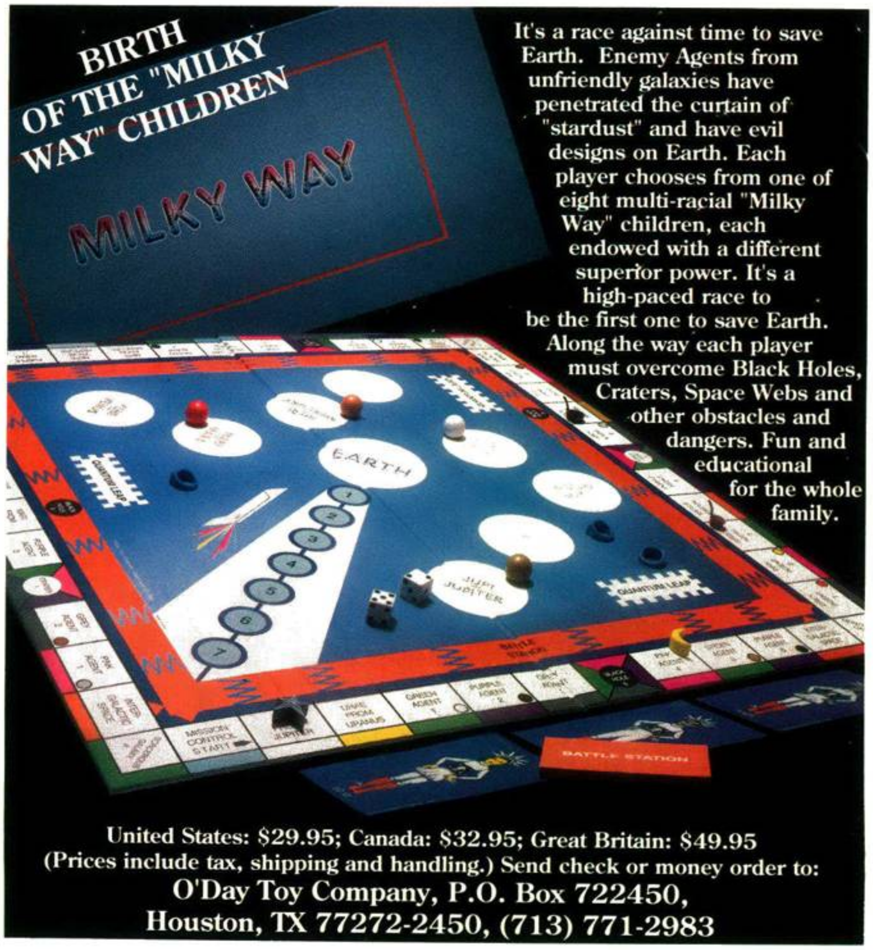

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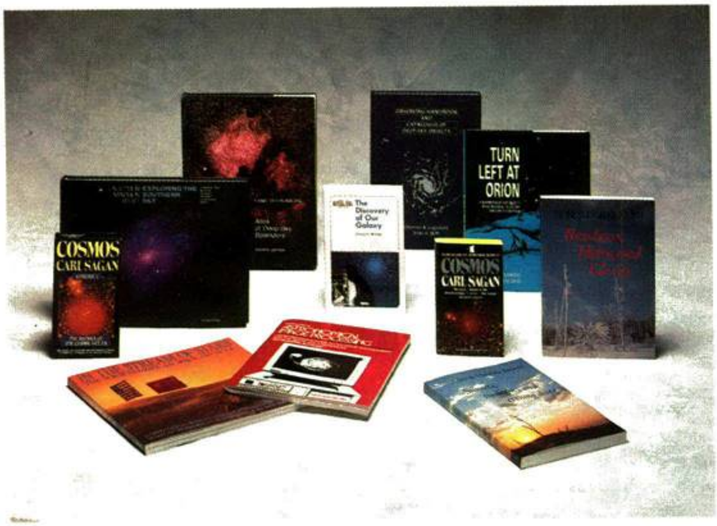

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Introduction to Astronomical Image Processing The first how-to guide to CCD image processing for the IBM - PC and compatibles. Includes software and test images. Ideal for computer-users, astrophotographers and skilled amateurs. By Richard Berry, Editor-in-Chief of ASTRONOMY magazine. 96 pgs., softcover. #30239/$29.95

Observing Handbook and Catalogue of Deep Sky Objects Detailed guide with information and descriptions for more than 2,000 galaxies, star clusters and nebulae. Includes helpful charts and advice on how to observe, plus a comprehensive catalogue. By Christian B. Luginbuhl and Brian A. Skiff, 352 pgs., hardcover. #30246/$49.50

Rainbows, Halos & Glories Discusses well-known phenomena such as rainbows and halos, plus sun pillars, sun dogs, glories and mirages. Contains over 200 illustrations, including full-color photos, plus detailed figures to help better understand these optical mysteries. By Robert Greenler. 195 pgs., softcover. #30243/$22.95

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Atlas of the Solar System This intriguing reference book provides the most up-to-date information on all aspects of the solar system. Written in encyclopedic style with over 700 photographs, illustrations and diagrams plus numerous maps and tables. By Patrick Moore and Garry Hunt. 463 pgs., hardcover. #30235/$17.99

Astrophotography A clearly written guide for the beginner. By Barry Gordon. 2nd Ed. 208 pgs., softcover. #30125/$19.95

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The Light Hearted Astronomer A wickedly funny story of buying a telescope and becoming an amateur astronomer. By Ken Fulton. 115 pgs., softcover. #18001/$7.95

Nightwatch This field guide to the universe provides you with a new, simple method of identifying stars, planets, constellations and nebulae. Chapters cover backyard observing, stargazing equipment, the planets and solar and lunar eclipses. By Terence Dickinson. 160 pgs., hardcover. #30229/$34.95

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Philip's Color Star Atlas Shows all naked-eye stars in beautiful color. With 20 wide-field maps and informative introduction. Ideal for naked-eye, binocular, small telescope and armchair astronomers. By John Cox and Richard Monkhouse. 40 pgs., softcover. Available September 1991. #18038/$19.95

The Quest for Contact NASA astronomer Dr. Jill Tarter narrates this fascinating video on the Search for Extra Terrestrial Intelligence. Includes interviews with Carl Sagan and other experts. Produced by NASA. 32 min. VHS #50159V/$29.95

The Quick Reference Guide to ASTRONOMY Magazine 1973-1990 A subject listing for easy access to articles, photos and features in ASTRONOMY magazine. By Jack Hobart. 75 pgs. #30226/$8.00

Space Places A unique portrait of how far we have traveled and what lies ahead in space exploration. Lavishly photographed and insightfully written, this book is a personal evocation of the people and technology in modern astronomy. By Roger Ressmeyer. 208 pgs., hardcover. #30232/$45.00

The Star Book Teach yourself the stars and constellations of the night sky – their names, locations and lore. By Robert Burnham, Senior Editor of ASTRONOMY. 17 pgs., softcover. #18002/$9.95

Star Names: Their Lore and Meaning A classic source for star legends, constellation lore and stories from celestial mythology. By Richard Hinckley Allen. 563 pgs., softcover. #30003/$8.95

A Starhopper's Guide to Messier Objects Find your way to the famed Messier objects from bright naked-eye stars. By Lenore Freeman. 25 pgs., softcover. #30042/$7.50

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Meetings & Events

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Twin Lakes Star Party. Sponsored by the West Kentucky Amateur Astronomers. Contact: Jim Boren, Land between the Lakes, Golden Pond, KY 42211-9001. Phone: (615) 232-7405 (days), (615) 232-6820 (evenings).

October 11-13
Connecticut Star Party, Colebrook, Connecticut. Sponsored by the Astronomical Society of New Haven. Contact: Astronomical Society of New Haven, P. O. Box 3005, New Haven, CT 06515.

October 12
Starfest '91. Contact: Bays Mountain Amateur Astronomers, 853 Bays Mountain Park Road, Kingsport, TN 37663.

October 16-19
27th Annual Conference of the Great Lakes Planetarium Association, Youngstown State University, Youngstown, Ohio. Contact: Warren Young, Ward Beecher Planetarium, Youngstown State University, Youngstown, OH 44555. Phone: (216) 742-3616.

October 18-20
AGAAC Association Congress, Sherbrooke, Québec. Sponsored by the Club des Astronomes de Sherbrooke. Contact: Luc Caya, 1185 Bayeux, Sherbrooke, Québec, Canada. Phone: (819) 562-3992.

October 19
Star Watch '91, Holcomb Observatory, Mooresville, Indiana. Contact: Indiana Astronomical Society, 2 Wilson Drive, Mooresville, IN 46158.

January 28 - February 2, 1992
8th Annual Winter Star Party, Camp Wesumkee, Florida Keys, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Bob or Sharon Grant, 5401 SW 110th Avenue, Miami, FL 33165. Phone: (305) 595-8778.

May 9
Astronomy Day. Contact: Gary Tomlinson, Astronomy Day Coordinator, Public Museum of Grand Rapids, 54 Jefferson SE, Grand Rapids, MI 49503. Phone: (616) 456-3987. ☐

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.

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ANNOUNCEMENT — The Ancient City Astronomy Club, Inc. meets every first Friday of the month at 8 p.m. in the First United Methodist Church, King Street, in St. Augustine, Florida. Write to P.O. Box 546, St. Augustine, FL 32085-0546 or phone (904) 797-5704 or (904) 471-3054.

WANTED — Desk edition of Becvar's *Atlas of the Heavens* in good condition. Contact Darian Rachal, 300 Cleco Dr., #106, Pineville, LA 71360. Phone (318) 442-1314.

FOR SALE —Celestron C-90 wedge, complete. Never used. $60. Inquire at 533 San Benito Avenue, Los Gatos, CA 95030. Phone (408) 395-6928.

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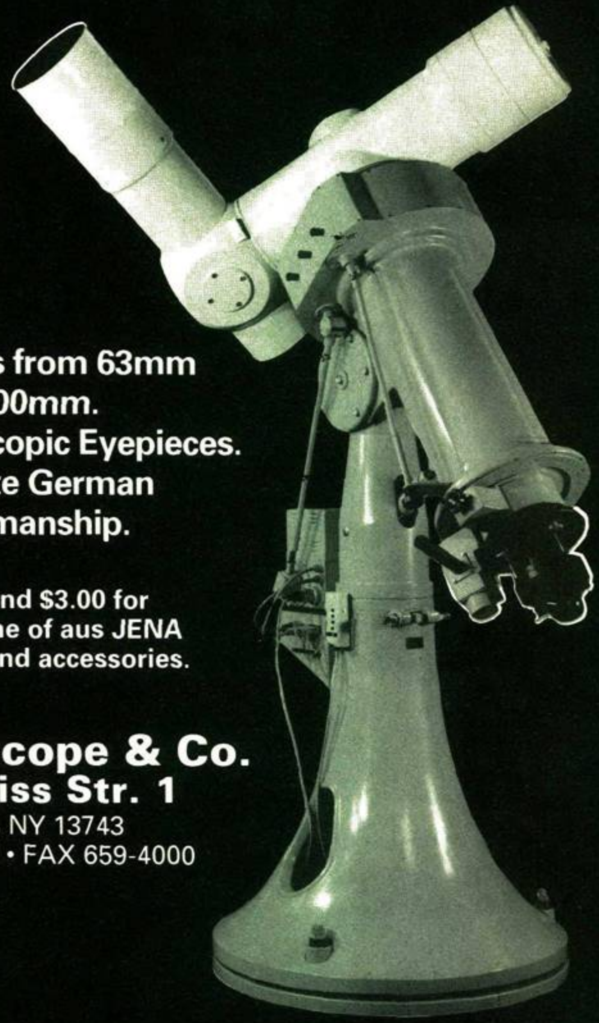

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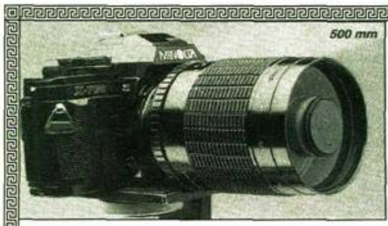

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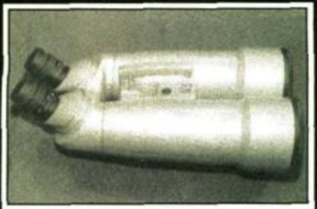

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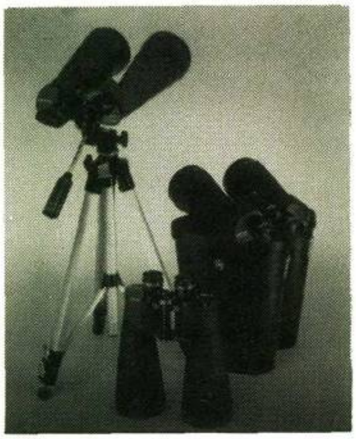

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Will the Lion Roar Again? (page 30)

"Comet Tempel-Tuttle and the Leonid Meteors," by Donald K. Yeomans, *Icarus*, v. 47, p. 492, 1981. A technical study of the dust distribution around the comet based on historical records of the shower and celestial mechanics.

Meteor Showers by Gary Kronk (Enslow, 1988). A detailed description and catalog of more than a hundred annual meteor showers, arranged by date of maximum; spends nine pages on the Leonids.

Smallest Stars (page 50)

Stars and Their Spectra, by James Kaler, (Cambridge University Press, 1989). A book for the interested lay reader that explores these stypes of stars (and others) in greater depth.

The Newtonian Advantage (page 69)

Astrophotography for the Amateur by Michael Covington (Cambridge University Press, 1985). One of the best introductory books for those interested in getting into astrophotography.

Great Galaxy in Andromeda (page 76)

"The M31 Globular Cluster System," by David Higgins, DEEP SKY #32 (Autumn 1990). Tells how to hunt for 21 globulars belonging to this large galaxy.

"All About M31," by Brian Skiff, DEEP SKY #8 (Fall 1984). Just what the title says, this is a comprehensive look at M31.

Buying Your First Telescope (Special Supplement)

The Backyard Astronomer's Guide by Terence Dickinson and Alan Dyer (Camden House, 1991). A new comprehensive guide to amateur astronomy with an emphasis on equipment selection and use. Contains several chapters of advice from the authors on buying binoculars, telescopes, and accessories.

"ASTRONOMY'S 1991Guide to Telescopes," October 1990. Lists lots of telescopes, with specifications, features, and prices.

CREDITS

Cover: Rajiv Gupta, 5-inch f/10 Astro-Physics refractor, 1/125-second exposure on Ektar 25 film from Baja, California, July 11, 1991; ***p. 4:*** Barney Magrath from Mauna Kea, Hawaii, on July 11, 1991; ***p. 24, all images:*** 120-inch Shane Telescope at Lick Observatory, courtsey University of California at Santa Cruz; ***p. 26:*** NASA; ***p. 32-43:*** see page 37; ***p. 45:*** engraving from ***The Midnight Sky*** by Edwin Dunkin; ***p. 46:*** engraving from ***Popular Astronomy*** by Camille Flammerion; ***p. 47:*** engraving courtesy of the American Museum of Natural History; ***pp. 48-49:*** illustration by Mark Watson, with data from Donald K. Yeomans; ***pp. 50-51:*** illustration by Michael Carroll; ***pp. 52-55:*** all photos and diagrams courtesy James B. Kaler; ***p. 57, top:*** Janos Papp, 55mm f/1.7lens, ASA 320 film, 4-minute exposure on November 4, 1981; ***pp. 68-69:*** John Mirtle, 6-inch f/4.5 reflector combined with 120-format Ektachrome 400 film; ***p. 70, top and center:*** John Mirtle, 6-inch f/4.5 Newtonian, Ektachrome 400 film with deep-sky filter, 40-minute exposure; ***bottom series:*** Alan Dyer; ***p. 71, top:*** John Mirtle, 6-inch f/4.5 Newtonian, 35-mintue exposure; ***bottom left:*** Alan Dyer; ***bottom center:*** John Mirtle, 8-inch f/6 Newtonian, 30-minute exposure; ***bottom right:*** John Mirtle, 8-inch f/6 Newtonian, 25-minute exposure; ***p. 72:*** John Mirtle, 8-inch f/6 Newtonian, hypersensitized Tech Pan 2415, 60-minute exposure; ***pp. 72-73:*** John Mirtle, 8-inch f/6 Newtonian, hypersensitized Tech Pan 2415, 40-minute exposure; ***pp. 74-75:*** John Mirtle, 8-inch f/6 Newtonian, hypersensitized Tech Pan 2415, 60-minute exposure; ***p. 76:*** Jeffrey Corder, 6-inch scope at f/30; ***p. 77:*** Tony Hallas and Daphne Mount; ***p. 78, top:*** Bill Iburg, 14-inch SCT at f/9, Ektachrome 400 film, 45-minute exposure using a cold camera; ***bottom:*** Preston Scott Justis, 10-inch f/6 reflector, 103a-0 film, 60-minute exposure; ***p. 79, top and bottom:*** Jack Newton, 16-inch f/5 reflector, 18-minute exposure; ***p. 80:*** Paul Roques, 16-inch f/4.5 reflector, hypersensitized Tech Pan film, 60-minute exposure; ***p. 81:*** Bruce D. MacDonald, 12-inch f/5 AstroMak, hypersensitized Tech Pan film, 120-minute exposure; ***p. 84-85:*** illustrations by Susan Schneck; ***p. 89:*** Matthew Boulton, 6-inch refractor at 213x, sketches made on March 29, 1991 (yellow filter), April 15 (integrated filter), May 1 (blue filter), May 7 (blue filter), June 13 (blue filter), and June 20 (blue filter); ***p. 90, top left:*** Bill and Sally Fletcher; ***bottom left:*** Tom Orzechowski; ***top right:*** Tom Dey; ***right center:*** Edwin Faughn; ***bottom right;*** Chris Cook; ***p. 91:*** Bill Sterne, Mamiya 645 camera, 80mm lens at f/8, 4-second exposure on Kodak VPH120 (ISO 400) film; ***How to Buy Your First Telescope (supplement), p. 1: wide-angle view of Milky Way:*** Mike Mayercheck, Nikon 35mm lens, 10-minute exposure, Fujichrome 1600 film; ***photo of silhouettes:*** Darla Gawelski and Chris Becker; ***p. 2:*** Larry Landolfi; ***p. 4, top left:*** Stellefane photo by Michael McCoy; ***top right, top center, bottom center, and bottom:*** Vic Canstonzo; ***pp. 5-15:*** all photos by Darla Gawelski and Chris Becker.

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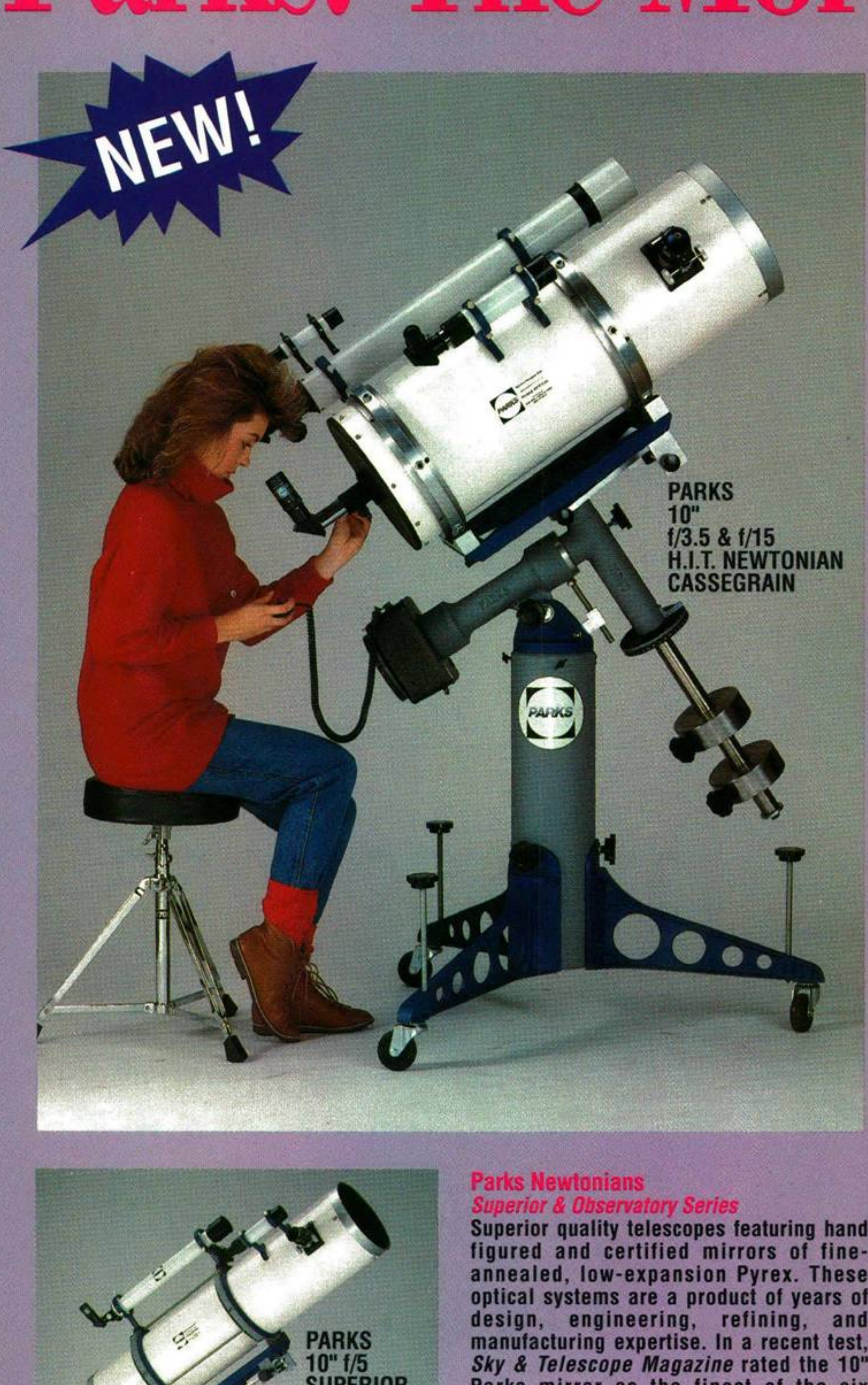

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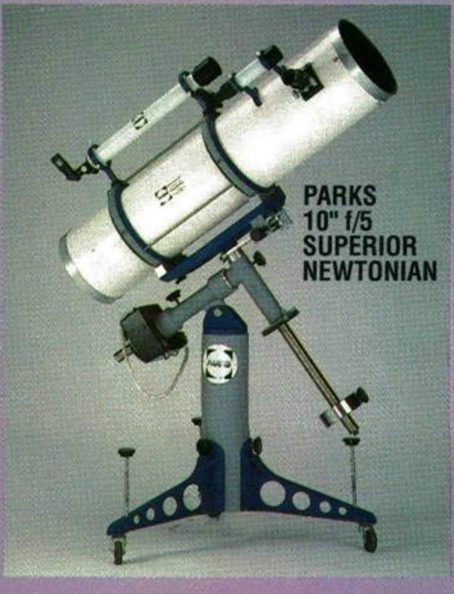

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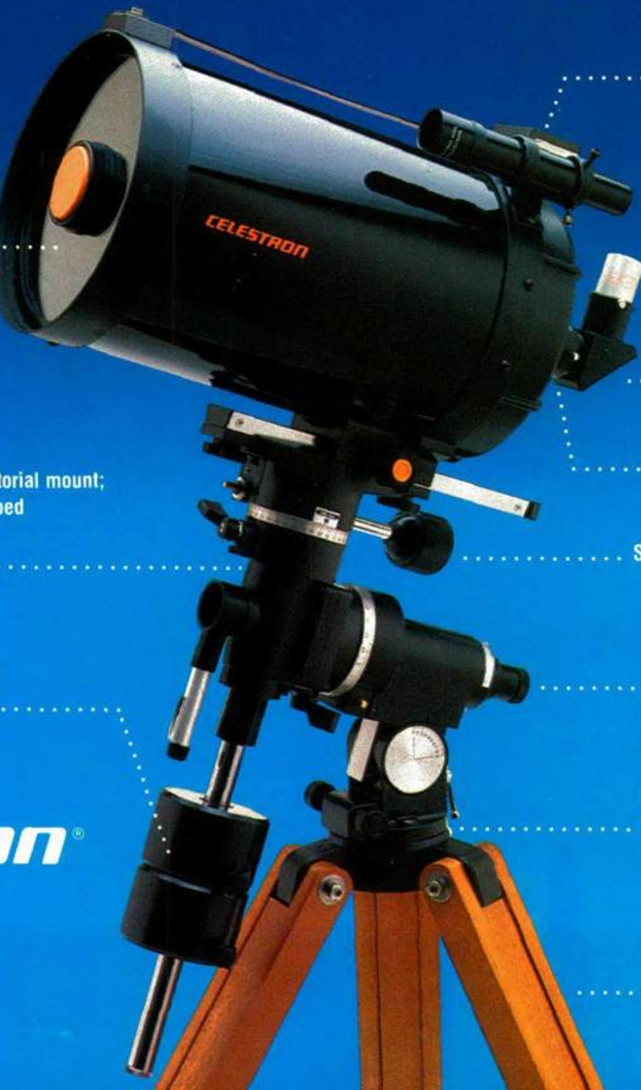
Its technically advanced gear system, stable tripod, plus many extras combine to make this mount an excellent investment—unmatched in performance at this price.

To see the Super Polaris C8, visit the Celestron dealer near you. Or write or phone Celestron for more information.


Piggyback mount
8" diameter, 2032mm focal length, f/10, Schmidt-Cassegrain
Celestron's own Starbright® coated optics
6x30 finderscope
CELESTRON
26mm Plössl multicoated eyepiece—1¼"
Multicoated star diagonal—1¼"
Visual back—1¼"
German equatorial mount; 144 tooth lapped worm gears in both axes
Slow motion controls
Adjustable counterweights
Built-in polar alignment scope for quick set-up
Latitude scale; bubble level
Adjustable wood tripod; (excellent vibration dampening)

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From the Editors
of ASTRONOMY
Magazine

How to Buy Your First Telescope

Buying Your First

Your Window on the Universe

It is quiet. The Sun has set, and with it go the worries of the day. The western horizon is tinged with the deep orange of twilight. Above the band of sunset color the sky fades into a deep, clear blue, punctuated by a few bright planets. Soon they will be joined by hundreds of stars. Though people describe this time as a curtain of night falling, you see it differently — as a curtain rising. You know the coming darkness will actually reveal a wide new stage on which the drama of the universe plays every clear night.

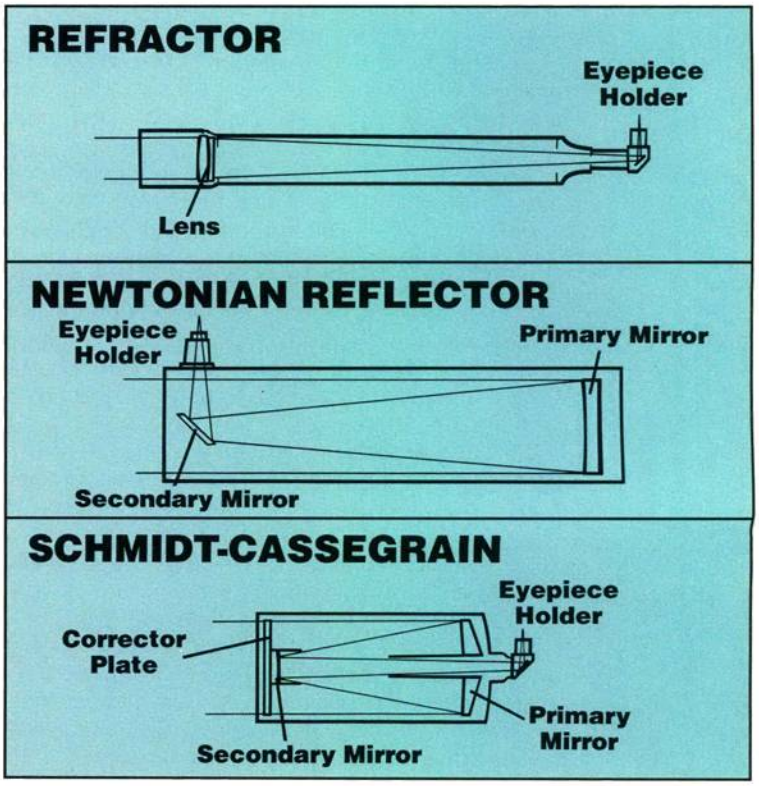
You have waited for this night. With the anticipation of an explorer about to set foot on a new continent or a new world, you set up your telescope. Under the twilit sky you check its fittings, orient its mount, insert a favorite eyepiece, and wait for the night to bring forth your list of chosen targets. Tonight it's a journey out to clusters of newborn stars along the Milky Way, then to a glowing cloud of interstellar debris cast off by an ancient supernova explosion. The journey will end with a glimpse of spiraling whirlpools of stars, galaxies so distant that their light — the light you'll capture tonight — has been traveling since the time of the dinosaurs. All this is within reach of your telescope.

When you own a telescope, each evening like this is a welcome time to escape beyond the confines of the world. It is an opportunity to extend your vision into the depths of space, to explore cosmic vistas few others have the chance to see. But the privilege is yours every clear night. Your telescope is your personal window on the universe.

Telescope

A Telescope Buyer's Top 30 Questions

Buying your first telescope can seem like a complicated affair. There are many models to choose from and many technical terms to contend with. To help you make the right choice, here are answers to 30 of the most-asked questions we get from prospective telescope buyers. We trust you'll find answers to your questions among them. If not, please call us at ASTRONOMY magazine [(414) 796-8776, Monday to Friday, 8:30 a.m. to 5:00 p.m. Central Time] or see your local telescope dealer.



TRIO OF TELESCOPES: REFRACTORS use lenses to collect and focus light. They combine ruggedness with crisp images.

A NEWTONIAN REFLECTOR uses a concave mirror at the bottom of the tube, which reflects light to a small, flat secondary mirror which then deflects the light to the eyepiece at the side of the tube.

In a SCHMIDT-CASSEGRAIN, a concave mirror reflects light to a convex secondary mirror which in turn sends the light back down to a focus at the rear of the telescope. A thin corrector plate at the front of the tube compensates for an optical distortion called spherical aberration.

1 How much does the telescope magnify?

Beware of any telescope advertised as "500x" or "high-power." Some manufacturers make it sound as if the more magnification a telescope offers, the better it is. This is not true. Contrary to the claims of department-store catalogs, *magnification is not the most important quality*. Any telescope can be made to magnify any amount. However, the highest power that will still give you a clear view is about 50x per inch of aperture, making the upper limit for a 3-inch telescope 150x and for a 4-inch telescope 200x. Beyond this limit, the image will be faint, fuzzy, and disappointing.

2 How, then, do I select the best telescope?

The key characteristic of a telescope is its aperture — the diameter of the main lens or mirror. The larger the aperture, the more light the telescope gathers and focuses into the image. This in turn makes for a brighter, and usually clearer, image. Brighter images make it easier to see faint objects like nebulae and galaxies.

3 Which are better — refractors or reflectors?

A refractor uses a lens mounted at the front of the telescope to gather and focus light. A reflector uses a concave mirror mounted at the back of the telescope. Both work well; each has its advantages. Reflectors generally offer more aperture for the money. (A 4-inch reflector costs $400 to $500; 4-inch refractors start at $1,000 or more.) However, refractors usually

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What Can I See?

What you can see through the eyepiece of a good telescope is enough to keep you exploring the sky for many years. Here's a bit of advice: when you unpack your first telescope and set it in the backyard on its premiere night under the stars, the first thing you should look at is the Moon. You won't need high power — 50x will be just fine. Even at this low power, you'll be amazed at the view — we guarantee it.

After observing the Moon, the first planet you should look at is either Jupiter or Saturn. (This winter or spring try for Jupiter; in summer or autumn try Saturn — the monthly "Sky Almanac" section of ASTRONOMY will tell you where to find them.)

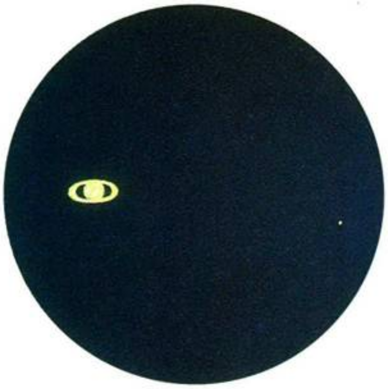
When you aim your scope at Saturn, be prepared for a remarkable sight. Most people utter an exclamation of "Wow!" when they first see Saturn and its picture-perfect rings.

Even a small 60mm-aperture telescope will reveal the cloud belts on Jupiter. Over the course of several nights, you'll see Jupiter's four large moons as bright dots shuttling back and forth from one side of Jupiter to the other.

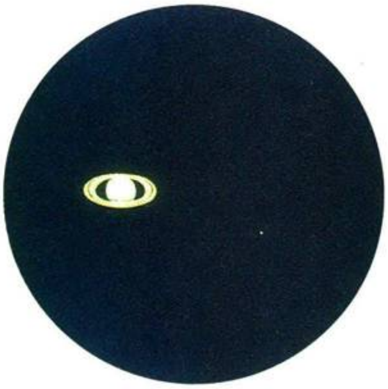
A telescope also allows you to follow the changing phases of Mercury and Venus, and to watch Mars grow and shrink in size as we approach and then recede from the Red Planet every two years. And, yes, Mars really does look orange-red. When it is closest to Earth, a magnification of 100x to 200x will show its reddish disk, dark surface markings, and famous polar caps. You can continue to tour the solar system by tracking down Uranus and Neptune, although even in large telescopes they appear only as tiny blue-green dots. Starlike Pluto is within reach of backyard scopes but requires at least an 8-inch-aperture instrument and dark skies.

Beyond the solar system there are hundreds of star clusters, nebulae, and galaxies within reach of 60mm- to 80mm-aperture scopes. Larger scopes reveal these deep-sky objects in even more detail and bring thousands more deep-sky wonders within reach. But don't expect to see the colors you see in photographs — the colors of nebulae and galaxies are so faint they show up only in long-exposure photographs. Most deep-sky objects appear as misty, gray patches of light. However, some stars show colors your unaided eye cannot see, and many stars that appear as single to the naked eye appear split into two or more stars through a telescope — they are systems of alien suns orbiting each other.

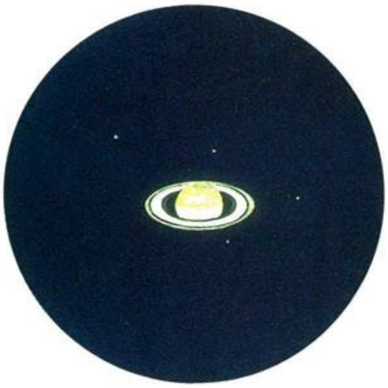
If you want an idea of how far you can see with a telescope, you can actually explore the most distant reaches of the cosmos by hunting down elusive galaxies. Because of their immense distances, these islands of stars are typically very faint. Nevertheless, from a dark rural site a 3- or 4-inch telescope will show many of these ghostly spots of light, enabling you to probe tens of millions of light-years into space. All with a telescope costing no more than a round-trip air fare to Europe. It's a bargain price for a ticket to the stars.



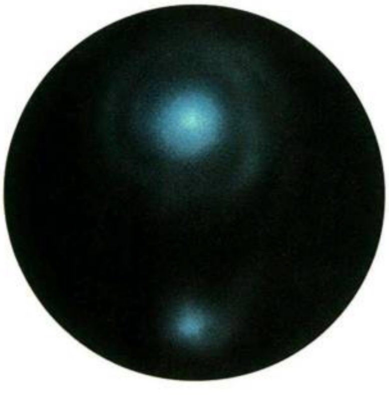
2-inch telescope (50x)



4-inch telescope (125x)



12-inch telescope (275x)



Whirlpool Galaxy (8-inch telescope)

provide slightly sharper images than reflectors of similar aperture. Amateur astronomers who like to view fine details on planets often prefer refractors; those who like to look at faint deep-sky objects use reflectors. For most first-time buyers on a budget, either an 80mm refractor or a 4.5-inch reflector is a good choice. Both cost $400 to $600 and have comparable performance.

4 What are Schmidt-Cassegrain telescopes?

A third type of telescope system, called a catadioptric, uses a combination of mirrors and a refractive corrector lens at the front. The most popular of these hybrid models is the 8-inch Schmidt-Cassegrain (prices start at $1,200). It folds a long focal length into a compact tube, making this type of telescope very portable and convenient to use for its aperture. It is also a good general purpose telescope suitable for observing all classes of celestial targets.

The two main manufacturers of this type of telescope are Celestron International and Meade Instruments Corporation. These two companies are competitive and offer a similar range of Schmidt-Cassegrains, from basic no-frills units to feature-laden computer-controlled models. Which company makes better telescopes? Over the years we have found that in optical and mechanical quality, both are nearly equal.

5 What are apochromatic refractors?

One of the principal problems with conventional refractors over 80mm aperture is spurious color around bright objects caused by the inability of the lens to bring all colors to the same point of focus. To greatly reduce this "chromatic aberration," manufacturers have introduced refractors that use 3-element lens systems or special fluorite or "ED" lenses. Called apochromatics, these high-end refractors are among the finest optical systems you can buy and have become popular with telescope aficionados. Models are available from Astro-Physics, Celestron, Takahashi, Tele Vue, Vernonscope/aus Jena, and Vixen. However, a 4-inch "apo" refractor can cost $2,500 to $5,000, more than most people wish to spend on a first telescope.

6 How much more will I see with a bigger telescope?

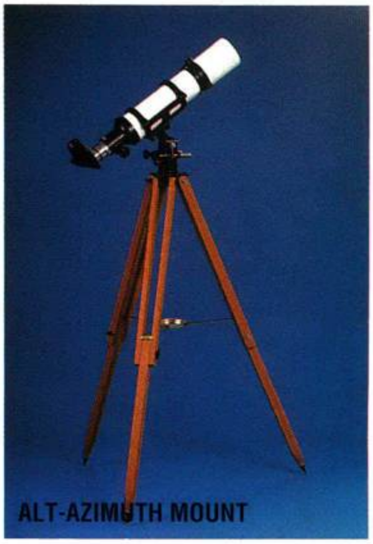
Bigger telescopes can show fainter objects and resolve finer details in bright objects. For example, a 2.4-inch (60mm) refractor will easily show the cloud belts of Jupiter, a 4-inch will show structure within the cloud belts, and an 8-inch will resolve even smaller details. A 4-inch will show globular star clusters as fuzzy-edged spheres of light, a 6-inch will resolve many globulars into myriad faint stars, and a 12-inch will provide views of these clusters that surpass any photograph. While a 4-inch will reveal a spiral galaxy as a round glow, an 8-inch will begin to reveal the galaxy's spiral arms.

A QUARTET OF MOUNTS:
ALT-AZIMUTH mounts swing left-to-right and up-and-down. They are inexpensive but cannot automatically track the stars.

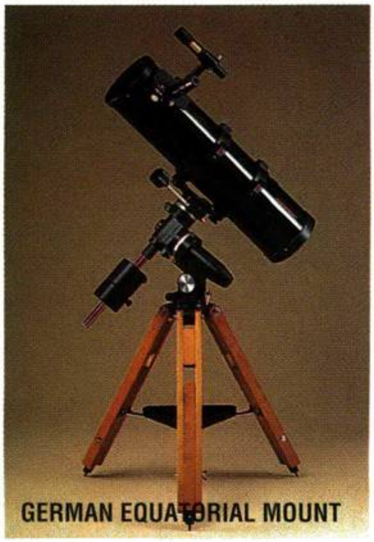
The DOBSONIAN mount is an alt-azimuth design often used on large reflectors.

The GERMAN EQUATORIAL mount can track the stars with a single motion. It is used with long-tube telescopes such as refractors. Motor drives are often options.

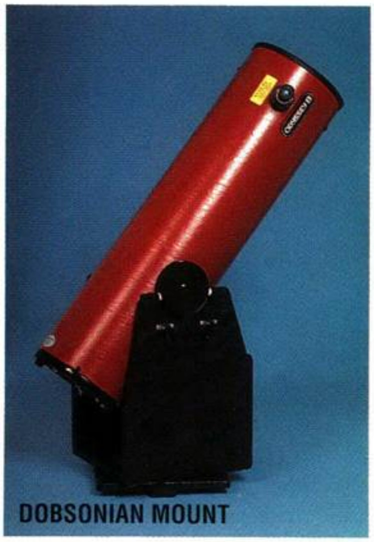
The EQUATORIAL FORK mount can also track the stars and is used on short-tube telescopes like Schmidt-Cassegrains. Motor drives are built into the base.



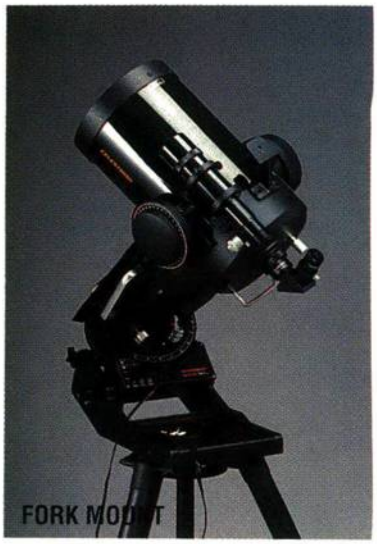
ALT-AZIMUTH MOUNT



GERMAN EQUATORIAL MOUNT

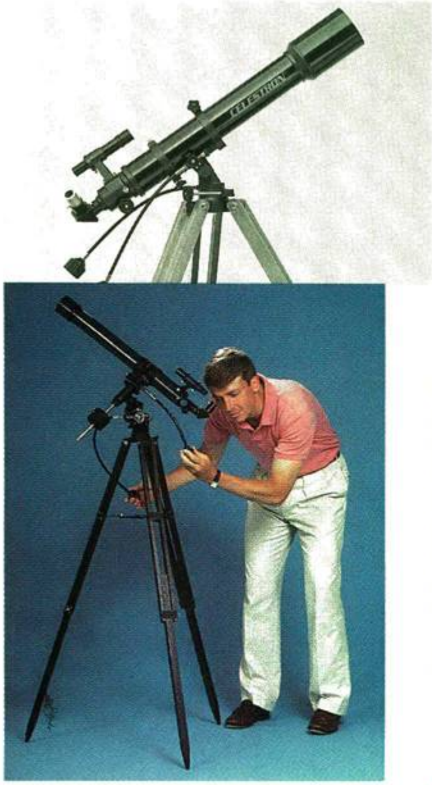


DOBSONIAN MOUNT

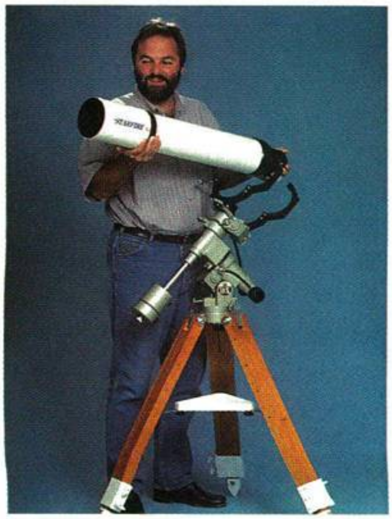


FORK MOUNT

REFRACTORS ARE POPULAR beginners' telescopes. The better grade of small 60mm models such as the Meade #290 (bottom) can get you started. But we recommend 80mm refractors, such as the alt-azimuth-mounted Celestron FirstScope 80 (below) or the similar Meade #312, as better choices.



HIGH-END REFRACTORS such as the Astro-Physics 4-inch apochromat (below) offer top-notch optics but at premium prices. Other competitive models are available from Celestron, Takahashi, and Tele Vue (their popular "Genesis").



7

Will I be happy with a smaller scope?

The fact that bigger telescopes usually show more details and fainter objects leads many people to believe small scopes aren't worth buying. But even an 80mm refractor can show you enough of the universe to keep you entertained for years. For many people it's all the telescope they ever need.

We warn people against buying a telescope that is too large — yes, there is such a thing. A big telescope, though exciting at first, can quickly become a burden to carry out to the yard or car and to set up. The best telescope is not the biggest, or even the one with the best optics, but *the one that you will use most often.* Portability and convenience are factors to consider when selecting a telescope that you'll have fun using.

8

I live in the city (country) where the skies are terrible (great). What type of telescope is best for me?

A large-aperture telescope can be useful at any site, but faint deep-sky objects (the kind big scopes are well-suited for) won't show up well under urban skies, no matter what size the scope. City observers often spend more time looking at the Moon and planets, for which a 3- to 8-inch telescope is sufficient. Telescopes in that size range are also very portable, an important consideration for city observers who need to transport their scopes to better skies. For most buyers, we feel that a 5-inch refractor, a 6-inch equatorial reflector, an 8-inch Schmidt-Cassegrain, or a 10-inch Dobsonian reflector (see question 16) are the largest telescopes of their types that are conveniently portable. Only if you live under dark skies, or really don't mind lugging a big, heavy scope around, should you consider anything larger for a first telescope.

9

What does focal length mean? And f/ratio?

The focal length of a telescope is the length of the light path from the main lens or mirror to the eyepiece. In most refractors or reflectors, the focal length is roughly the length of the tube. In telescopes such as Schmidt-Cassegrains in which the light path is bounced back and forth inside the tube several times, the length of the tube is much shorter than the focal length. Focal lengths of telescopes, like camera lenses, are usually measured in millimeters.

The f/ratio of a telescope is the focal length divided by the aperture. For example, a 100mm-aperture telescope with a 900mm focal length is an f/9 telescope. A 200mm telescope (an 8-inch) with a focal length of 1,800mm is also an f/9.

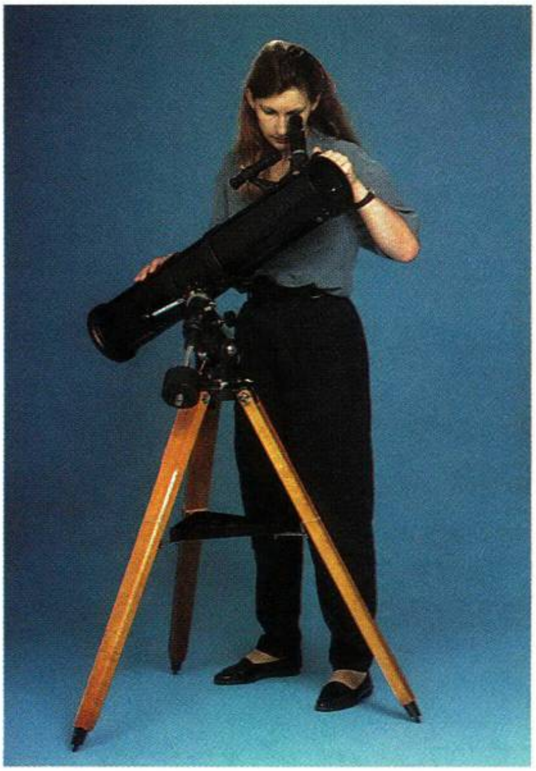
10

What focal length is best?

The focal length of the telescope is not a critical specification. Telescopes with shorter focal lengths (400 to 700mm) will give lower powers and wider fields of view with a given eyepiece than telescopes with moderate (800 to 1,200mm) or long focal lengths (1,300 to 3,000mm). For this reason, short focal lengths are often preferred for wide-angle viewing of deep-sky targets and Milky Way starfields. On the other hand, a long-focal-length scope will give a higher power with any given eyepiece. Since the planets require higher powers (100x to 200x), planetary fans often prefer long-focal-length scopes. But with the use of the appropriate eyepieces, most telescopes can be used at both low and high powers.

11 How can a telescope be "fast" or "slow"?

Sometimes manufacturers give the impression that a "faster" telescope (one with an f/ratio of f/4 to f/6) is better than a "slow" telescope (f/7 to f/16). After all, in many situations faster *is* better. But in this case it isn't. The term "faster" comes from photography, where an f/4 lens will record an image with a faster exposure time than an f/16 lens will. And for those intending to take long-exposure photos through a telescope, faster scopes can be better. But when you look through a telescope, a faster telescope does not give brighter images than a slower scope. For example, as long as both are operating at the same power, the image in an 8-inch f/6 telescope will appear as bright as the image in an 8-inch f/10 scope. The difference is that with the same eyepiece the f/6 telescope will give a lower power and a wider field of view than the f/10 will, making faster scopes preferred for deep-sky observing where wide fields are desirable.



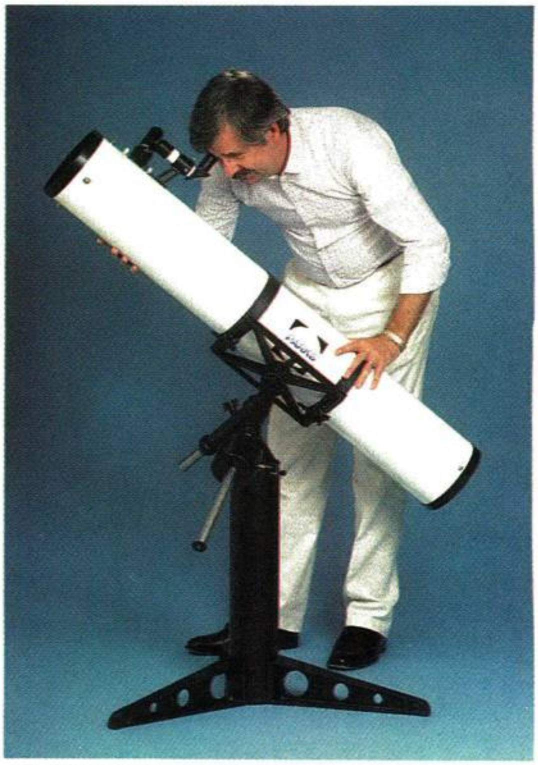
12 What is an eyepiece for?

Eyepieces allow you to change magnification of the image formed by the lens or mirror. To determine the magnification an eyepiece gives, divide the focal length of the telescope by the focal length of the eyepiece. For example, a 25mm focal-length eyepiece used on a 2,000mm focal-length scope (such as an 8-inch f/10 scope) will give 2000/25 = 80x. The same eyepiece used on a 1,600mm scope (such as an 8-inch f/8) will give 64x.

REFLECTORS OFFER THE MOST aperture for the money. The Celestron C4.5 (above) is one of the best of many 4.5-inch reflectors on the market. A 6-inch reflector, such as the Parks 6-inch f/8 Precision (below) costs more but makes a superb all-purpose telescope.

13 What is the little scope for?

The little scope you see on many telescopes is a finderscope. It is an essential accessory. It provides a low power (5x to 8x) and a wide field (3° to 5°) and allows you to aim the telescope easily and center it on bright planets and stars. Without a finderscope, locating even the Moon can be difficult.



14 Why are images in telescopes upside-down?

All astronomical telescopes present images that are either upside-down or flipped left-to-right as in a mirror. To flip the image right-side up would require extra lenses in the light path that would dim the view of already faint astronomical objects or add imperfections like flares and ghost images.

15 Which is better — an alt-azimuth or equatorial mount?

Alt-azimuth mounts use simple up-down (altitude) and side-to-side (azimuth) motions to aim the telescope. The best of these mounts are equipped with slow-motion controls that allow you to make fine adjustments to the position of the scope. However, alt-az mounts cannot automatically follow the stars as they arc across the sky from east to west.

An equatorial mount is more complex. It *can* follow the stars across the sky with a single motion around one axis. If the telescope is equipped with a motor, the telescope will automatically track the stars. This is a nice feature because at magnifications of 100x or more, the apparent motion of the sky will cause objects to drift out of the field of view in less than a minute. Having to recenter the image constantly can be distracting and inconvenient, and can introduce vibration that shakes the image.

OFTEN CALLED "LIGHT BUCKETS," Dobsonian-mounted reflectors, such as this Coulter Odyssey 8, offer lots of aperture on an ultra-simple but steady mount. Deep-sky explorers willing to sacrifice features and finish for aperture and low price love Dobsonians.

16 What about Dobsonian telescopes?

A Dobsonian is a Newtonian reflector. Its unique feature is a simple wooden alt-azimuth mount that rides on Teflon pads. The philosophy of the popularizer of this type of telescope, John Dobson, was to keep the scope easy-to-build and low-cost. The design also lends itself to relatively large apertures. Dobsonians cannot track the stars automatically, but their motions are very smooth — it's easy to nudge the scope every so often to recenter the object.

As of 1991, only one manufacturer was selling low-cost Dobsonian telescopes — Coulter Optical Company. Their models offer big aperture for very little money (for example, a 10-inch reflector for under $400). People often wonder if there's a catch. There are a few: Coulter scopes are in such demand that you may have to wait several months to a year for delivery. You must order directly from the factory and pay shipping costs from their plant in California (which may add up to $100 to the cost). You will also need to add a finderscope. The fit and finish of the scopes is nothing fancy — the mounts are painted chipboard, the tubes cardboard. Our opinion? *For the money,* the quality of construction and optics can't be beat. The 8- and 10-inch Coulter models make good starter scopes. The 13- and 17-inch models are best for die-hard deep-sky observers.

17 I've heard you can make your own telescope.

The Dobsonian design lends itself to do-it-yourselfers. Plywood for the mount and a cardboard tube like those used for concrete forms are the main ingredients. Few people make their own mirrors these days. It can be done, but ready-made mirrors from suppliers like Coulter, Meade, and Parks don't cost much more than mirror-making kits. You'll also need a focuser and cells to hold the main mirror and the small secondary mirror. For more information about telescope making, see the book *Build Your Own Telescope* by Richard Berry, available from Kalmbach Publishing.

18 What accessories do I need?

Some telescopes come with only one eyepiece. Additional eyepieces for higher and lower powers are the first accessories most first-telescope owners need to buy. An accessory called a Barlow lens can double or triple the power of each eyepiece, but the best Barlows (the only ones worth buying, trust us!) cost $80 to $100.

Colored filters can enhance views of the planets slightly, but the difference is subtle. They are not essential. Nebula or light-pollution filters can improve views of some deep-sky objects like emission and planetary nebulae, but they do little to improve star clusters and galaxies. Contrary to what many beginning backyard astronomers believe, these filters are not a cure-all for light-polluted skies.

Computerized digital readouts to aid in finding objects have become popular telescope accessories in recent years. They work well but are luxury options for those that can afford their $500 to $1,000 price tags.

19 Are enhanced coatings worth the extra cost?

Some telescopes are offered with special lens or mirror coatings as optional extras (Celestron's Starbright™ and Meade's MCOG, for example). These increase the light transmission, yielding images up to 15 percent brighter. They are definitely worth the extra expense.

Performance Specs

Aperture (inches)	Aperture (mm)	Faintest Star[1]	Resolution[2] (arcseconds)	Highest Usable Power[2]
2.4	60	11.6	2.0	120x
3.1	80	12.2	1.5	160x
4	100	12.7	1.2	200x
5	125	13.2	1.0	250x
6	150	13.6	0.8	300x
8	200	14.2	0.6	400x
10	250	14.7	0.5	500x
12.5	320	15.2	0.4	600x
14	355	15.4	(0.33)	(600x)
16	400	15.7	(0.3)	(600x)
17.5	445	15.9	(0.27)	(600x)

[1] The faintest star visible for that size telescope using the magnitude scale, where a mag. 6 star is the faintest the unaided eye can see, mag. 11 is 100 times fainter, and mag. 16 is 100 times fainter again. Using superb optics under ideal conditions, experienced observers can often exceed these values by a magnitude or more.

[2] Under most atmospheric conditions, even in large telescopes, magnifications over 500x to 600x and resolutions better than 0.4 to 0.5 seconds of arc are rarely possible.

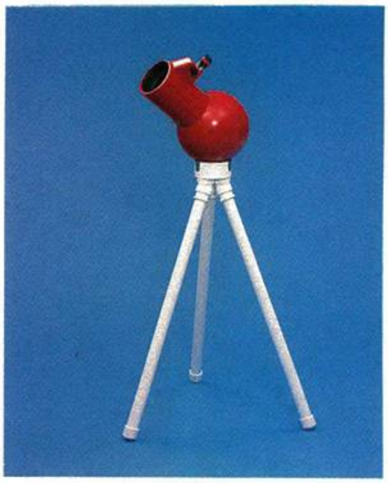
20 Can I use setting circles to find things?

Many equatorial mounts are equipped with graduated dials called setting circles. Theoretically, these allow you to find objects by moving the telescope so that the circles' readings match the celestial coordinates (called right ascension and declination) of the object you're looking for. However, in our experience we have rarely seen a novice amateur astronomer (nor many experienced ones!) who have been able to make effective use of setting circles. Poor alignment of the telescope mount, improperly calibrated circles, and imprecise circle scales usually combine to make circle readings inaccurate. The best method to find celestial targets is to hop from star to star using a good star chart as your guide. Plan on buying such a star chart as an essential accessory.

21 Can I take pictures with this scope?

Anything you see through a telescope can be photographed, but most objects require exposures of several seconds to an hour or more. Keeping the object perfectly positioned on the film during that time requires a solid equatorial mount and a motor drive. These are essential features if you intend to do astrophotography.

PORTABILITY IS A CRITICAL FACTOR for many people. Compact telescopes such as the Meade 2045 4-inch Schmidt-Cassegrain (above) and the Edmund Astroscan (below) are easy to carry and set up anywhere with little fuss. The 4.2-inch Astroscan reflector, a fine starter scope, is shown sitting on a homemade plastic-pipe tripod.



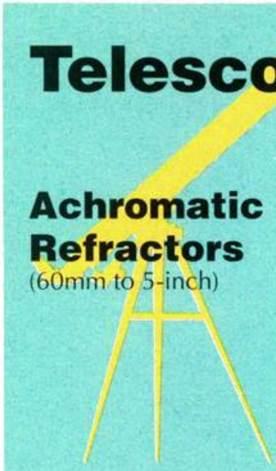
22 Can I use a spotting scope for astronomy?

Some spotting scopes (such as those sold for birding) have only a fixed-power eyepiece or a variable zoom eyepiece. These models are not well suited for astronomy. Other models use interchangeable eyepieces but must be placed on a solid camera tripod. Because they lack fine slow-motion controls, camera tripods are difficult to aim precisely, a problem at high power.

23 But I also want to use my telescope for nature observing.

If your interests mix astronomical and terrestrial viewing, we suggest an 80mm or 4-inch refractor or a small 4-inch Schmidt-Cassegrain. Don't buy a Newtonian reflector — the position of the eyepiece makes a Newtonian awkward for use as a spotting scope.

Telescope Pros and Cons



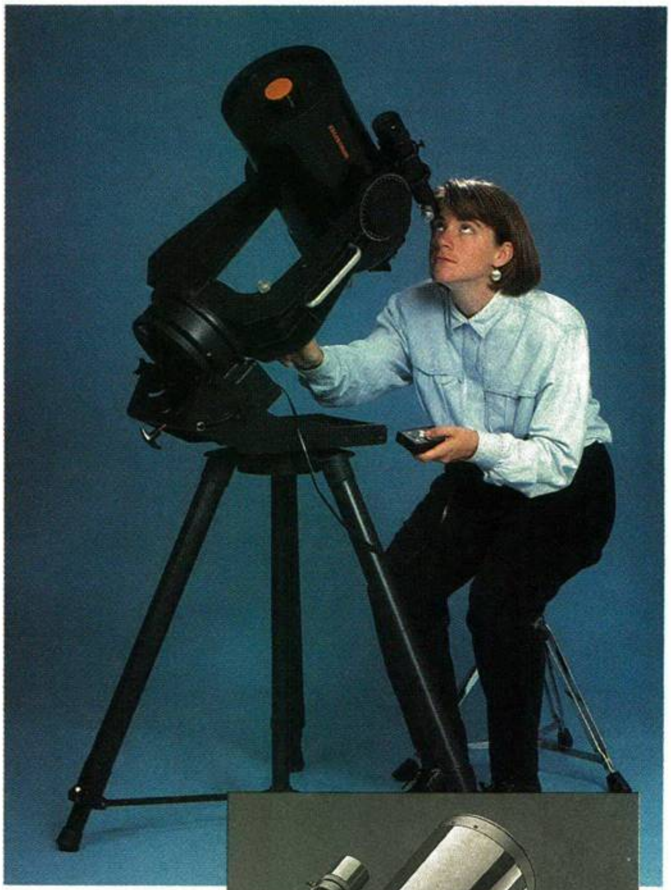
	The Pros	The Cons
Achromatic Refractors (60mm to 5-inch)	Economical in smaller sizes; rugged; portable; easy to aim; usually provide sharp images.	Small apertures have limited light-gathering power; larger apertures exhibit chromatic aberration.
Apochromatic Refractors (3- to 7-inch)	Provide high-quality images near perfection; excellent for lunar and planetary viewing; fast models good for wide-field, deep-sky viewing and photography.	Relatively expensive for the aperture; light-gathering power cannot compete with that of larger reflectors.
Equatorial Newtonian (4- to 18-inch)	Large aperture for the money; small sizes are excellent scopes for serious beginner. In f/6 to f/8 designs, they are good all-purpose scopes.	Can be very bulky and heavy in sizes over 8 inches; mirrors require adjustment; mirror surfaces are exposed and can get dirty.
Dobsonian (8- to 20-inch)	Biggest aperture for least money; portable for the aperture; superb for deep-sky observing; easy to set up (no polar alignment); great for dark-sky sites.	Optical quality in low-cost models is a compromise; mount does not track the stars; mirror collimation critical in fast f/ratio models.
Schmidt-Cassegrain (4- to 11-inch)	Very portable for an equatorially mounted scope; easy to set up and aim; adaptable for astro-photography; expandable systems with many accessories; good general-purpose telescopes.	Outperformed by specialized telescopes for planetary (refractors and long-focus Newtonians) and deep-sky viewing (large Dobsonians); corrector plates attract dew.

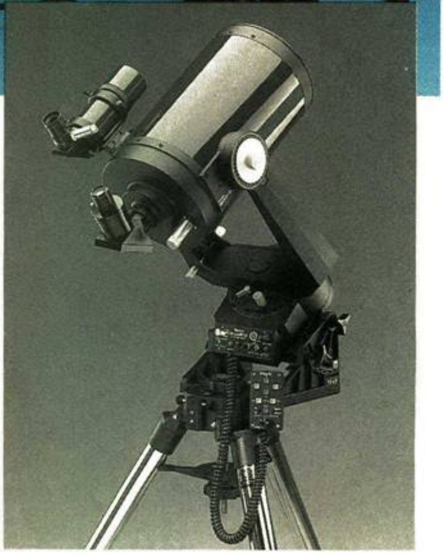
24 How much should I have to spend?

We feel that $400 to $500 is the minimum for a quality starter scope such as an 80mm refractor or 4.5-inch reflector. The next step up is to a 6-inch equatorially mounted reflector (such as the models from Celestron, Meade, or Parks Optical). These sell for $600 to $900. The next level up that many first-time buyers consider is an 8-inch Schmidt-Cassegrain ($1,200 to $2,500). No-frills Dobsonian reflectors defy these price/aperture categories by offering much more aperture for the money (see question 16).

25 What does "$^1/_{20}$th-wave optics" mean?

The deviation of an optical surface (lens or mirror) from the ideal shape is often stated as a fraction of a wavelength of light. The smaller the fraction, the better the optics and the sharper the image. However, to be meaningful for a complete telescope, this deviation figure should be provided for the final wavefront reaching the eye, not just for individual lenses or mirrors. When measured in this manner, a telescope with a total error on the final wavefront of $^1/_4$ wave is good, $^1/_8$ or $^1/_{10}$ wave is excellent, and $^1/_{20}$ wave is outstanding though seldom achieved. Manufacturers have no agreed-upon standard for measuring these values — one company's $^1/_{20}$ wave may be equivalent to another company's $^1/_{10}$ wave.





26 What does "diffraction limited" mean?

This is another freely used term in telescope advertising. It means that the optics are so good they are limited only by the wave nature of light and not by any flaws in the surface accuracy of the lenses or mirrors. Specifically, it means the final wavefront error is better than $^1/_4$ wave, a figure known as Rayleigh's Criterion. Few manufacturers have the technical equipment to quantitatively support this claim. Most test telescope quality by ensuring units form good star images. Although this *is* a very sensitive test that will detect small flaws in the optics, it cannot guarantee a numerical specification like $^1/_4$ wave.

27 Where can I buy a good telescope?

We suggest shopping at a local telescope dealer if there is one near you (check the Yellow Pages under "Telescopes"). Good dealers will check each scope they sell, provide good service, answer your technical questions, and perhaps allow you to take home a scope on a trial basis. You can at least see what you're getting before you buy it. This peace of mind is worth any extra cost involved.

Mail-order companies that specialize in astronomy products can also offer personal service (over the phone) and money-back guarantees of satisfaction. We would caution you about some (not all) mail-order firms — their prices may be heavily discounted but at a sacrifice of expert personal service. Some have limited guarantees and no after-sale service — if there is a problem you can find yourself on your own dealing directly with the manufacturer. Also, watch the shipping and packing charges!

ONE OF THE MOST POPULAR TELESCOPES for serious backyard astronomers is the 8-inch Schmidt-Cassegrain. It offers aperture, portability, and convenience. A wide range of models is available from Celestron International (such as their Ultima 8, at top) and from Meade Instruments (above). Above photo courtesy Meade Instruments.

EDITORS' CHOICES
UNDER $400 TELESCOPES

Model		Aperture	f/ratio	Mount	Slow-motion control	Motor type	Finder	No. of eyepieces	Focuser size (in.)	Retail price
REFLECTORS										
Edmund Scientific	Astroscan 2001	4.2	4.2	AA	–	–	–	1	1.25	$380
Meade Instruments	#4420	4.5	8	GE	√	opt.	5x24	1	1.25	$380
Orion Telescope	SpaceProbe 4.5	4.5	7.9	GE	√	opt.	6x30	2	0.965	$400
Coulter Optical	Odyssey 8	8	4.5	DOB	–	–	opt.	1	1.25	$275
Coulter Optical	Odyssey Compact	10	4.5	DOB	–	–	opt.	1	1.25	$350
REFRACTORS										
Orion Telescope	TeleVista	2.4	11.6	AA	√	–	5x24	2	0.965	$200
Jason Empire, Inc.	#307 Explorer	2.4	13.3	AA	√	–	5x24	3	0.965	$275
Meade Instruments	#291	2.4	15	GE	√	opt.	6x30	2	0.965	$280
Orion Telescope	Sky Explorer 60	2.4	15	GE	√	opt.	6x30	2	0.965	$350
Edmund Scientific	#31-611	2.4	8	EF	–	–	5x24	1	1.25	$390
Meade Instruments	#312	3.1	11	AA	√	–	5x24	1	1.25	$400

AA = Alt-azimuth; DOB = Dobsonian; GE = German equatorial; EF = Equatorial fork . Prices are actual retail as of mid-1991.

EDITORS' CHOICES
$400 to $1,000 TELESCOPES

Model		Aperture	f/ratio	Mount	Slow-motion control	Motor type	Finder	No. of eyepieces	Focuser size (in.)	Retail price
SCHMIDT-CASSEGRAINS										
Meade Instruments	#2045D	4	10	EF	√	DC	5x24	1	1.25	$800
REFLECTORS										
Tasco*	#11TR	4.5	7.9	GE	√	opt.	5x24	2	0.965	$450
*Same as Jason #327, Simmons #6450, and Swift #853.										
Celestron	C4.5	4.5	7.9	GE	√	opt.	5x24	1	1.25	$550
Parks Optical	f/6 or f/8 Precision	6	-	GE	opt.	opt.	6x30	1	1.25	$800
Parks Optical	f/6 or f/8 Astrolight	6	-	GE	√	opt.	8x50	–	2	$850
Celestron	SP-C6	6	5	GE	√	opt.	6x30	1	1.25	$900
Meade Instruments	#826C	8	6	GE	–	AC	8x50	1	2	$800
Meade Instruments	DS–10	10	4.5	GE	–	AC	–	1	2	$800
Coulter Optical	Odyssey 1	13.1	4.5	DOB	–	–	opt.	1	1.25	$575
REFRACTORS										
Meade Instruments	#323	3.1	11	GE	√	opt.	5x24	1	1.25	$460
Celestron	Firstscope 80	3.1	11.4	AA	√	–	6x30	1	1.25	$550
Orion	Sky Explorer 80	3.1	15	GE	√	opt.	6x30	2	0.965	$550
Tasco*	#17TR	3.1	11.3	GE	√	opt.	6x30	3	0.965	$600
*Similar to Jason #324.										
Celestron	SP–C80	3.1	11.4	GE	√	opt.	6x30	1	1.25	$750
Vixen/celestron	Custom 90M	3.6	11	AA	√	–	6x30	3	0.965	$650
Vixen/celestron	SP-90M	3.6	11	GE	√	opt.	6x30	3	0.965	$850

AA = Alt-azimuth; DOB = Dobsonian; GE = German equatorial; EF = Equatorial fork . Prices are actual retail as of mid-1991.

28 What about buying a used telescope?

If well cared for, a used telescope should perform as well as a new one. You can find telescopes in the classifieds in local newspapers and "bargain finders." You should also check with your local astronomy club or ASTRONOMY's Reader Exchange. A newsletter called *The Starry Messenger* (advertised in ASTRONOMY) is devoted to ads for used telescopes.

29 What telescope would YOU buy?

This is impossible to answer. Someone who has been in the hobby for a while and who has already owned several telescopes would not select the same scope a first-time buyer would. Some people prefer the solidness and precision of a fine-quality refractor, others like the aperture and versatility of a Schmidt-Cassegrain, while others prize the light-gathering power and simplicity of a large Dobsonian reflector. There is no single best telescope. In fact, chances are the first telescope you buy will not be the last. Many backyard astronomers happily own two or three telescopes, each chosen for a certain type of viewing.

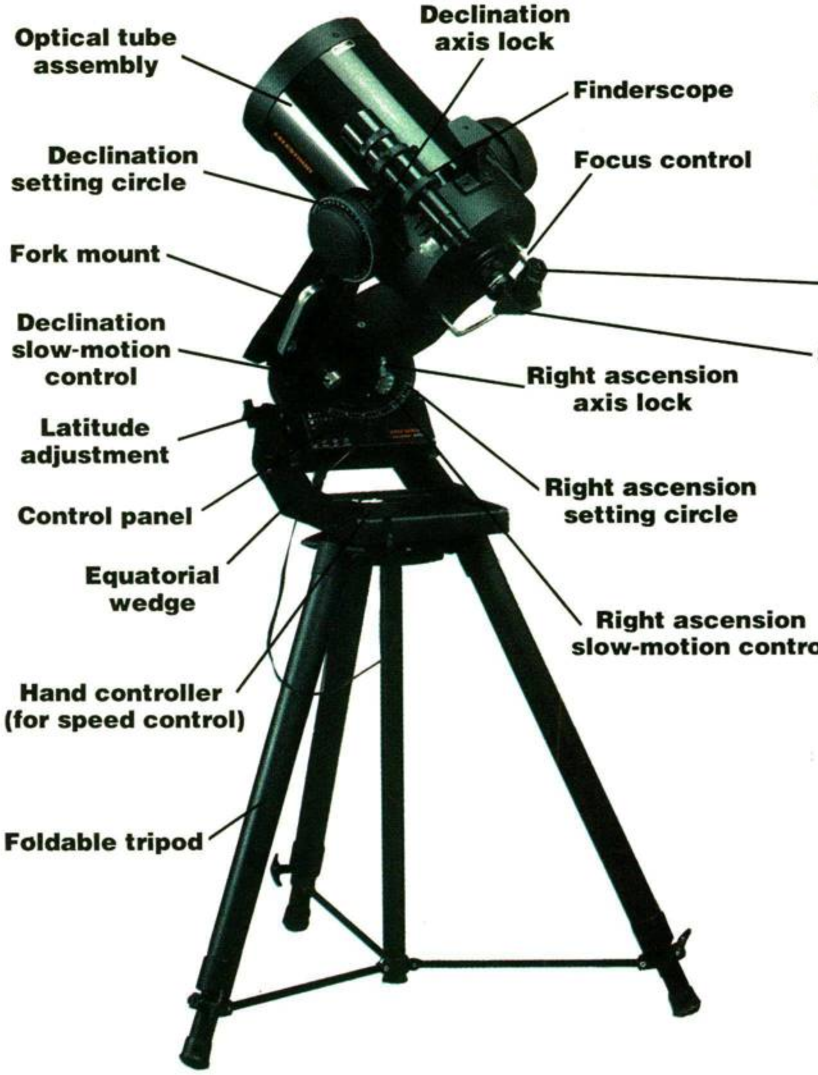
BUYING ACCESSORIES can keep you busy (and poor!) for years. But one or two extra eyepieces, a red flashlight, a good star atlas, and perhaps a few filters are all you really need.

EDITORS' CHOICES
$1,000 to $3,000 TELESCOPES

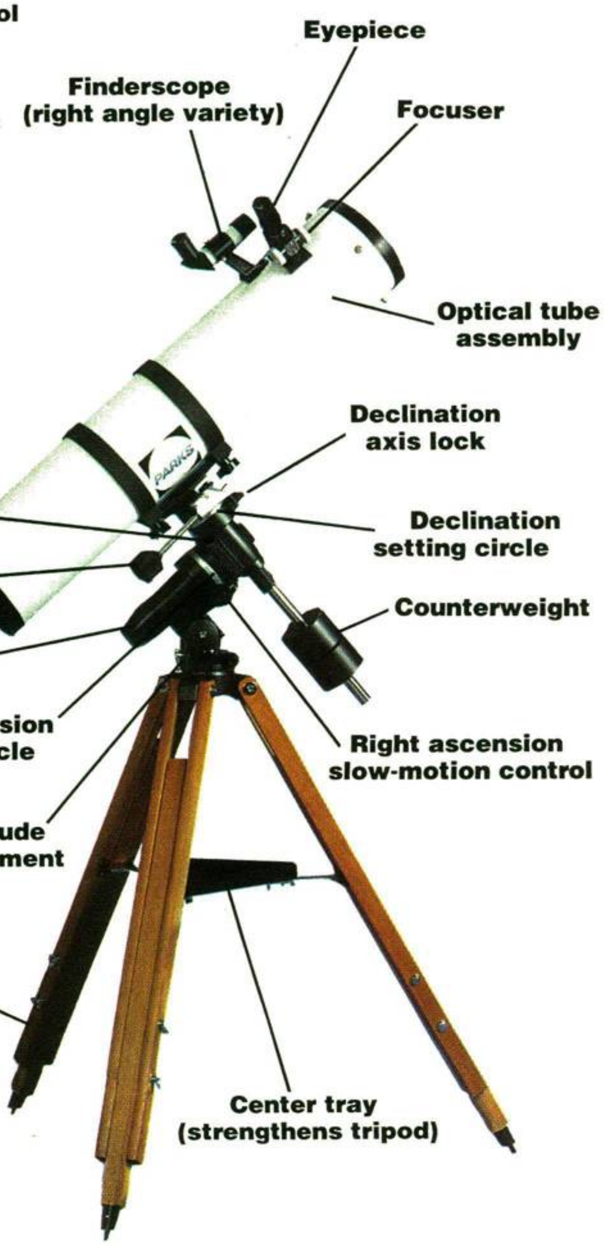
Model		Aperture	f/ratio	Mount	Slow-motion control	Motor type	Finder	No. of eyepieces	Focuser size (in.)	Retail price
SCHMIDT-CASSEGRAINS										
Meade Instruments	#2080B	8	10	EF	√	AC	6x30	1	1.25	$1,150
Celestron	Classic 8	8	10	EF	√	AC	6x30	1	1.25	$1,200
Celestron	Powerstar 8–PEC	8	10	EF	√	DC	6x30	1	1.25	$1,800
Meade Instruments	Premier 2080-40	8	10	EF	√	DC	6x30	1	1.25	$1,850
Meade Instruments	Premier 2080-50	8	10	EF	√	DC	9x60	2	2	$2,200
Celestron	Ultima 8–PEC	8	10	EF	√	DC	8x50	2	1.25	$2,300
REFLECTORS										
Parks Optical	8" f/6 Precision	8	6	GE	opt.	opt.	6x30	1	1.25	$1,100
Parks Optical	8" f/6 Superior	8	6	GE	√	DC	8x50	2	2	$2,200
Parks Optical	10" f/5 Superior	10	5	GE	√	DC	8x50	2	2	$2,600
Tectron	15" Dobsonian	15	5	DOB	–	–	–	–	2	$2,250
Coulter Optical	Odyssey 2	17.5	4.5	DOB	–	–	opt.	1	1.25	$1,150
REFRACTORS										
Takahashi	FC–76ES Apo	3	7.9	GE	√	DC	7x50	1	2	$2,500
Vixen/Celestron	SP-Fluorite 90S	3.6	9	GE	√	opt.	6x30	2	1.25	$1,900
Celestron	SP–C102	4	9.8	GE	√	opt.	6x30	1	1.25	$1,250
Televue Optics	Genesis Apo	4	5	GE	√	opt.	opt.	1	2	$2,500
Celestron	SP–C102F Apo	4	8.8	GE	√	opt.	6x30	1	1.25	$2,500
Astro–physics	4" Starfire Apo	4	8	GE	√	DC	opt.	–	2.7	$2,950
Astro–physics	Star 12ED Apo	4.7	8.5	GE	√	DC	opt.	–	2.7	$3,000

AA = Alt-azimuth; DOB = Dobsonian; GE = German equatorial; EF = Equatorial fork . Prices are actual retail as of mid-1991.

TYPICAL SCHMIDT-CASSEGRAIN ON FORK MOUNT


Optical tube assembly
Declination axis lock
Finderscope
Declination setting circle
Focus control
Fork mount
Eyepiece
Declination slow-motion control
Star diagonal
Right ascension axis lock
Latitude adjustment
Right ascension setting circle
Control panel
Equatorial wedge
Right ascension slow-motion control
Hand controller (for speed control)
Foldable tripod

TYPICAL TELESCOPE ON GERMAN EQUATORIAL MOUNT


Eyepiece
Finderscope (right angle variety)
Focuser
Optical tube assembly
PARKS
Declination axis lock
German equatorial mount
Declination setting circle
Declination slow-motion control
Counterweight
Polar axis finderscope (under cover)
Right ascension setting circle
Right ascension slow-motion control
Latitude adjustment
Extendable tripod
Center tray (strengthens tripod)

30 I have a child interested in astronomy. What scope should I buy? My budget is $200.

Avoid low-cost 500-power "department store" 50mm and 60mm refractors. Their poor mounts, eyepieces, and finderscopes will almost certainly make these telescopes a disappointment. The better 60mm refractors on alt-azimuth or equatorial mounts with slow-motion controls and a decent 6x30 finderscope *can* serve as starter scopes if your expectations are well-tempered. Acceptable models are available from astronomical dealers (such as those who advertise in ASTRONOMY) and local telescope stores.

But the truth of the matter is that for $200 (a common budget of parents with young astron-omers), there are few telescopes on the market we can endorse. Instead, we and many astronomy educators usually recommend a pair of 7x50 binoculars combined with a set of introductory books and star atlases, a package that will cost $100 to $200. Binoculars can reveal a surprising number of celestial objects (craters on the Moon, the moons of Jupiter, deep-sky objects such as star clusters and nebulae). A year spent exploring the sky with binoculars and a star chart can teach any novice astronomer, young or old, an immeasurable amount about the sky, the identity of stars and constellations, and the locations of celestial targets. If your prospective astronomer is still interested in the hobby after a year of binocular stargazing, then purchase a decent telescope for $400 to $500. At that point you will be more confident that your money will be well-spent. □

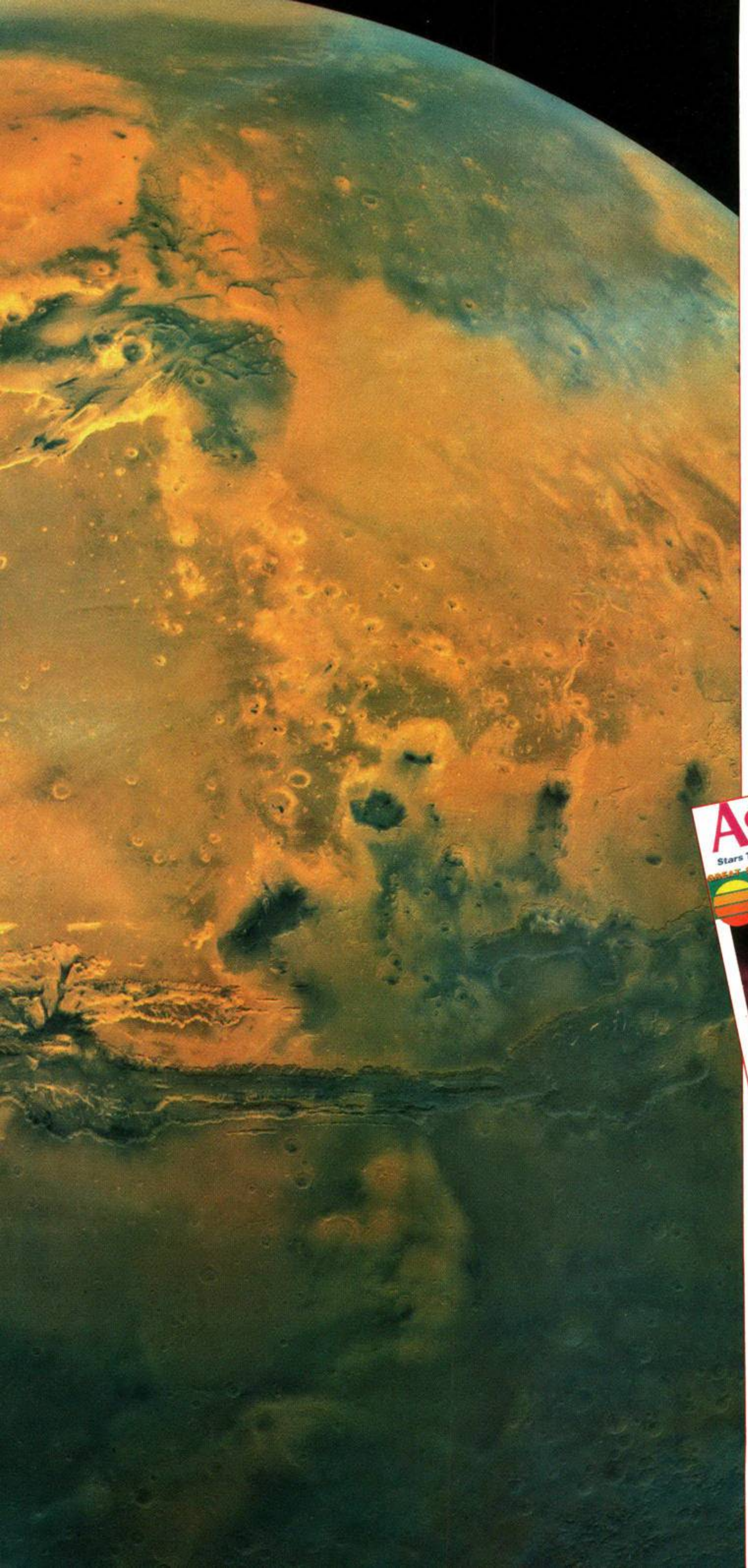
We trust we've been able to clarify the mysterious world of telescopes for you. To learn more about the various models on the market, we invite you to peruse the pages of ASTRONOMY *magazine each month. In each issue you'll find advertisements telling you where to write to manufacturers and dealers for product literature and catalogs. You'll also find independent tests of products conducted by the staff of* ASTRONOMY.

Please note that in this booklet we set an upper price limit of $3,000 for the most expensive telescope on our lists. However, you may be willing to spend more than that for a first purchase. If so, you have lots to select from, as the demands of ardent amateur astronomers have created a boom in high-end telescopes in recent years. Again, we refer you to ASTRONOMY *for ads and information on these models.*

Taking the time to research your purchase is a good idea. It's even a lot of fun. But don't agonize over the decision. With the exception of the department-store 60mm refractors we warned you about, there are few lemons on the telescope market. It's true that you may, like most backyard astronomers, soon outgrow your first telescope. But here's a final word of advice — long-time astronomers who end up owning many telescopes over the years often find that their first telescope, as basic as it was, was the one that provided them the most enjoyment. The moral: keep your first telescope no matter what telescopes you later buy. You can then always recapture the thrill of your first sight of the universe.

Buyer's Checklist

√ **Does the scope have sufficient aperture?**
We suggest at least a 4-inch for deep-sky objects.
√ **How good are the optics?**
Will the dealer provide a guarantee of satisfaction?
√ **How steady is the telescope?**
After a light tap, vibrations should damp out in 1 to 2 seconds.
√ **How portable is the telescope?**
Can you carry it easily? Will it fit in your car?
√ **How easy is it to set up?**
Is the mount complicated? Heavy? Does it require tools?
√ **Does it have a drive motor? Is it AC or DC?**
DC drives can run directly from batteries and have a wider range of speed controls.
√ **Does the mount have slow-motion controls?**
These make it easier to aim the scope and follow objects.
√ **Does it have a separate finderscope?**
Finders that sight through the main optics are usually very poor.
√ **How large is the finderscope?**
A 25mm-aperture finder is poor, a 30mm OK, a 50mm best.
√ **What diameter eyepieces does it come with?**
0.965-inch-diameter models are usually poor. 1.25-inch is better.
√ **How good are the eyepieces?**
Orthoscopic and Plössl eyepieces are better than Kellners.
√ **Does it come with a case?**
It's useful if you will be transporting the scope.
√ **How expandable is the telescope?**
Is there a good array of accessories available?
√ **Does it come with a warranty?**
And who will honor the warranty with service?



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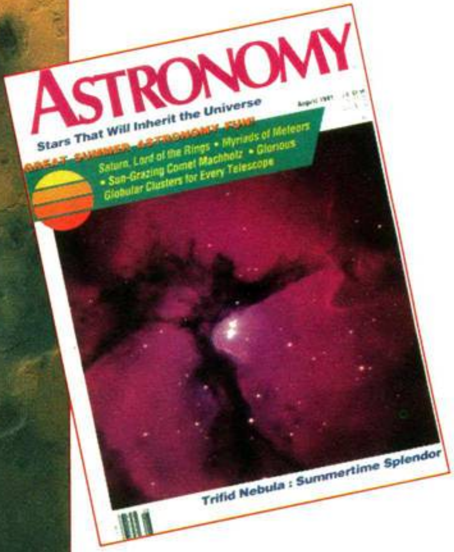
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